MODERN PAPER-MAKING

by

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and

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FOREWORD

A SUCCESSFUL paper mill must be dynamic and not static; hence the need for a periodic revision of any standard work like *Modern Paper-Making*. After reading this fascinating and exhaustive work the inclination is, like Oliver Twist, to ask for more. We could wish that such experts on mill practice could have found space for a chapter on Labour and Management to help us to solve the many problems which will arise after the present War is over. Our industry will then have to find room for those who have been serving in the Forces. When the last War ended in 1918 the majority of mills were able to solve the problem by changing from a two-shift system to three shifts. Are we prepared to be courageous and change over to a four-shift system and work over the weeks-ends as some industries do now? If we do then we shall need more Assistant Managers and extra Foremen, and for those who aspire to these positions this book should prove invaluable.

SYDNEY D. WHITEHEAD

STONECLOUGH,
August, 1941

PREFACE TO SECOND EDITION

THIS second edition, in a revised form, was thought necessary on account of the very great demand for the book from students and paper-makers during the last few years, by which time the first edition was out of print.

Unfortunately, however, when the work was nearly completed, the war intervened and caused unending delays and many difficulties.

Modern Paper-Making has practically been re-written in the light of fresh experience and new methods which have been adopted during the last ten years, and assistance has been sought from acknowledged experts in the various fields covered.

We are indebted to Dr. Bates for the chapter on Wood Pulp, and also to Mr. G. F. Underhay for the very excellent chapter on the Manufacture of Newsprint. Our thanks are also due to the many manufacturers of paper-making machinery and others for the loan of blocks for the illustrations, and to Mr. A. Hugh Rutt for the section dealing with paper conditioning.

We should also like to express our thanks to Mr. Potts for his photograph of the Suction Couch Roll, and to Mr. Binns for great help with the chapter on the Testing of Paper. We are also indebted to Kenneth Ross for his very painstaking assistance with the correcting of the proofs, and to Mr. A. B. Calligan for drawings and diagrams.

R. H. CLAPPERTON
WILLIAM HENDERSON

GREENFIELD,
YORKSHIRE,
April, 1941

PREFACE TO THIRD EDITION

OWING to the great demand for this book it has been necessary to reprint it. During the time which has elapsed between 1941 and 1946 there has not been sufficient change in paper-making practice in general to warrant re-writing the book. It is, therefore, presented again in almost the same form, and it is hoped that it will fill the want, which has frequently been expressed, for more copies of the book to become available, both in this country and abroad.

R. H. CLAPPERTON
WILLIAM HENDERSON

GREENFIELD,
YORKSHIRE,
1947

CONTENTS

ILLUSTRATIONS

CHAPTER I

FIBROUS MATERIALS USED IN THE MANUFACTURE OF PAPER

A SHEET of paper consists chiefly of a collection of vegetable fibres, of different lengths and sizes, twisted and interlaced with each other, and finally squeezed together, to make a sheet or web with a surface suitable for writing and printing.

The *strength* of paper depends to a great extent, though not entirely, on the length and strength of the individual fibres which go to make it, and also on the character of the fibres themselves.

The *quality*, or kind of paper made, depends on the *nature* of the fibres. As the fibres from different plants are in themselves different in structure, length and purity, it is necessary, first of all, to have some knowledge of the nature and appearance of the various fibres.

Fibres are the 'bones' of all plants. Just as the bones of animals are the framework on which are built up the living bodies, so are the fibrous elements of plants the supporting framework of the living plant.

Fibres from plants are the raw material of the paper-maker, and to obtain these fibres free from the protoplasm, or living juices and matters which are contained in and surround the fibres, is the first work he has to undertake. When so obtained, the fibres are termed 'cellulose'.

Fibres are too small to be seen distinctly with the naked eye, but the characteristics can be readily distinguished and examined with the aid of a microscope.

We shall concern ourselves chiefly with the five principal materials illustrated: Cotton, Linen, Esparto, Wood and Straw.

With the single exception of Cotton, all these fibrous materials are made up of varying proportions of cellulose and lignin, together with rosin, silica and plant juices, and it is this substance, cellulose, to which they have to be reduced in the pulp or paper mill.

Cellulose, as we know it in the mill, is a white, fibrous substance, having the chemical formula $C_6H_{10}O_5$, which means that six atoms of carbon are combined with ten atoms of hydrogen and five atoms of oxygen, to form one molecule of cellulose.

In isolating cellulose from plants, chemical and mechanical processes are necessary, differing for the various plants under treatment. These processes are chiefly directed to the removal of the various impurities, gums, resins, starch and other natural products of growth from the plant, leaving the cellulose more or less pure. Lignin is the life juices (or their resulting gums or resins) of the plant, intimately bound up with the cellulose. Being, therefore, cellulose imperfectly formed, or in process of being formed, it may be removed by chemical means, which, in some cases, just fall short of the destruction of the cellulose proper.

Cotton is the purest form of cellulose which nature produces. It requires practically no preliminary treatment to render it fit for paper-making.

Each of the celluloses produced from the various raw materials mentioned is, however, different from the others in the size, length, strength and structure of its fibres. They have therefore different paper-making properties.

As a simple illustration, these different fibres may be likened to the various sticks or branches which may be cut from different trees or bushes; for although all these consist of wood, yet they are far apart in texture, strength and form; one stick may be hard and brittle, such as elm or beech, another tough and whippy, such as ash or willow, a third long and straight, such as bamboo or cane. All these grow in various but definite forms, and each has its use in a different way.

All fibres are tubular—that is, they have an outside wall and a hollow centre. The thickness of this outside wall and consequent narrowness of the central canal or 'lumen', as it is called, varies with the different fibres, and has its effect on the ultimate properties or quality of the finished paper.

Cotton (Fig. 1, No. 1).—The cotton fibre is a single slender hair or cell, which grows out from the end of the cotton seed. It was probably evolved as a covering or protection for the seed, or an attraction for the insects which transfer pollen from one plant to another and so fertilize the seeds. The cotton plant is cultivated principally in India, Egypt and America, from whence the fibre is exported to such places as Lancashire for spinning and making into cotton goods. The latter, in the form of rags of all descriptions, is our raw material, but it is also used in the natural form, when we receive it as the refuse of cotton-seed oil and cake works, mixed with seed husks and dust. This 'recovered' fibre is called cotton 'linters'.

The cotton fibre is a comparatively long, flat tube, its average length being about 1 inch, while its width is about $\frac{1}{1000}$ or $\frac{1}{1200}$ part of an inch; in other words, 1000 or 1200 fibres placed side by side would take up 1 inch of space.

The central canal of this tube, during the period of growth, contains the juices which build up the fibre. When growth ceases, these juices dry up and

the tube collapses on itself and takes on a twisted form, something like a cork-screw, or a rubber tube which has had the air sucked out of it. This peculiar formation is of great interest and value to the paper-maker.

The fibre has a thin outside wall and a wide canal. The twisted, corkscrew form taken up by the cotton fibre is very characteristic, and may be clearly seen in the illustration. This is the chief reason why cotton produces a paper that is soft, flexible and bulky. The fibres will not pack closely together as

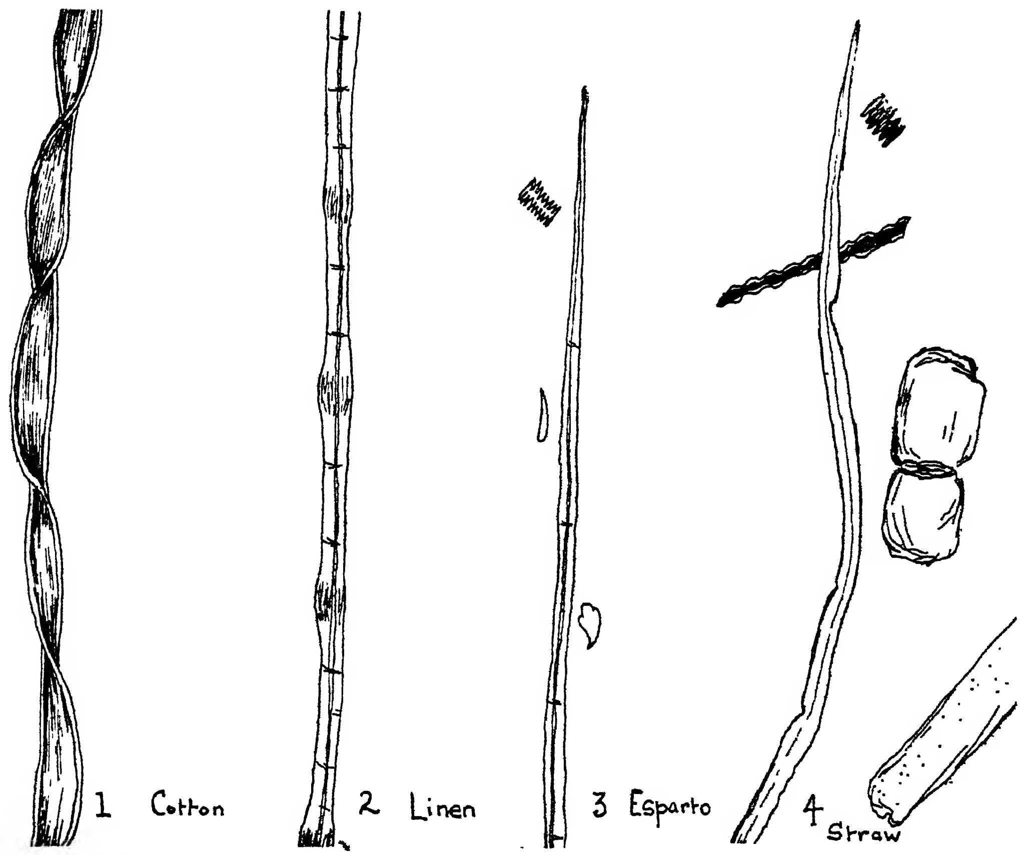


FIG. 1.—THE FIBRES OF COTTON, LINEN, ESPARTO, AND STRAW, WITH CHARACTERISTIC CELLS

flat fibres do. They are opaque, white in colour, with no pores or cross-markings, and the ends are round, blunt points.

In the process of paper-making, the appearance of these fibres is very much altered. The blunt ends are often destroyed, and are rarely seen under the microscope. The curious twist is not so prominent, and the fibres are torn and shredded.

Although, as mentioned already, cotton fibres will not lie closely together owing to their twisted formation, nevertheless, under the influence of the flow

and shake on the machine wire, this formation causes them to become inter locked with each other, and adds great strength to the paper, in addition t flexibility and bulk.

In order to give a clear explanation of this fact, we will again take th illustration of a number of sticks cut from different trees or bushes.

Suppose we have a dozen sticks or faggots cut from a thorn tree or hedge They will be more or less twisted and irregular in shape. On the other hand a bundle of canes will be composed of pieces more smooth and straight. Th faggot bundle will be more *bulky* than the other, because the sticks will no lie so closely together. Further, if we try to pull out the sticks from the firs lot, we will find it very difficult to do so, but we can pull the canes out quit easily.

Good new cotton (from rags, not raw fibre) when carefully beaten wil produce the strongest papers, as strong as those made from linen. It requires however, less drastic treatment in the beater than linen, because it is not sc easy to make 'wet' or 'greasy' without cutting the fibres too short. The cottor fibre is used for making a very great variety of papers, either alone or mixec with other fibres.

It is ideal for filter- and blotting-papers, being easily and quickly cut; it wide central canal and the spaces between the irregularly-shaped surfaces make plenty of room to be filled by the ink, or to allow liquids to pass through.

In short, the cotton fibre is one of the most adaptable that the paper-make has at his command.

Linen (Fig. 1, No. 2).—Linen is the fibre obtained from the flax plant, which is grown in most parts of the world, and especially in the North of Ireland, Russia and Central Europe.

The fibre is what is known as a bast, or inner bark fibre, and it is obtained from inside the stem of the flax plant by removing the bark or outer covering. The removal of this bark is a somewhat difficult operation, and is accomplished by leaving the cut flax lying in ditches or water to rot or 'ret'. This is known as the 'retting' process. In this way the outer bark is softened and rotted away.

After the retting is completed, the flax is collected and sent to the spinning and textile factories, where it is spun into linen thread.

A linen thread is never so even and regular as a cotton thread, owing to the hardness of the linen fibre and the knots which it contains; it is, however, smoother and more 'shiny' on its surface. The length of the linen fibre is about the same as cotton; it is about 1 inch long and grows in tight bundles inside the stem of the plant; it is very narrow, about 1200 to the inch, but it is much thicker-walled than cotton, and in consequence its central canal is much narrower.

The fact that it is thick-walled accounts for its being much stiffer and stronger than the cotton fibre. It is round, or rather polygonal, in shape, and not flattened. Its curious shape is due to tight packing of the fibre bundles in the stem during growth. As cotton may be distinguished under the microscope by its flatness and corkscrew bends, so the linen fibre may be distinguished by its knots or nodules, which give it the appearance of a piece of bamboo, by its small central canal, and, under high magnification, by cross-markings caused by the bending of the stem during growth. These characteristics may be easily seen in the accompanying sketches.

Linen fibres were among the first to be used for making paper, thousands of years ago, by the Chinese. Nowadays linen seldom forms the entire furnish of a paper, one reason being that it is scarce, and consequently expensive, and another its extreme 'wetness' in working, which renders it very difficult to make strong, thick or even medium-weight papers with it on a Fourdrinier machine.

Linen is used chiefly in such papers as strong loans, thin banks, tissues and cigarette papers, and in bank-notes and currency papers such as Bank of England notes. Its great value is in conjunction with cotton, to stiffen up and give strength to loans, ledger papers and thin banks.

Wood Fibres (Fig. 2, Nos. 1, 2, 3 and 4).—The fibres obtained from wood may be said to consist of two kinds, for although they are ultimately the same, the fibres from mechanical wood, as they come to the mill, are different, both in appearance and properties, from those which come in the form of chemical wood pulp.

Mechanical wood pulp is distinguished from chemical wood pulp in that it is prepared from the tree or log by purely mechanical means; that is, it is ground up into a sort of sawdust in water, and receives no chemical treatment whatsoever to free it from liquid resins, etc. It is very impure, and the fibres are short and brittle and often united in clumps by medullary rays.

The illustrations show clearly how these mechanical wood fibres differ from the chemical wood fibres, and a glance at them will make it apparent how very different are their properties as paper-making materials. The fibres obtained from wood by one or other of the chemical processes are fairly long—they vary very much in length—although shorter than those of cotton or linen. They are wide in comparison to their length and they are flat and sometimes twisted. The fibre walls are usually 'pitted' with small pores or holes.

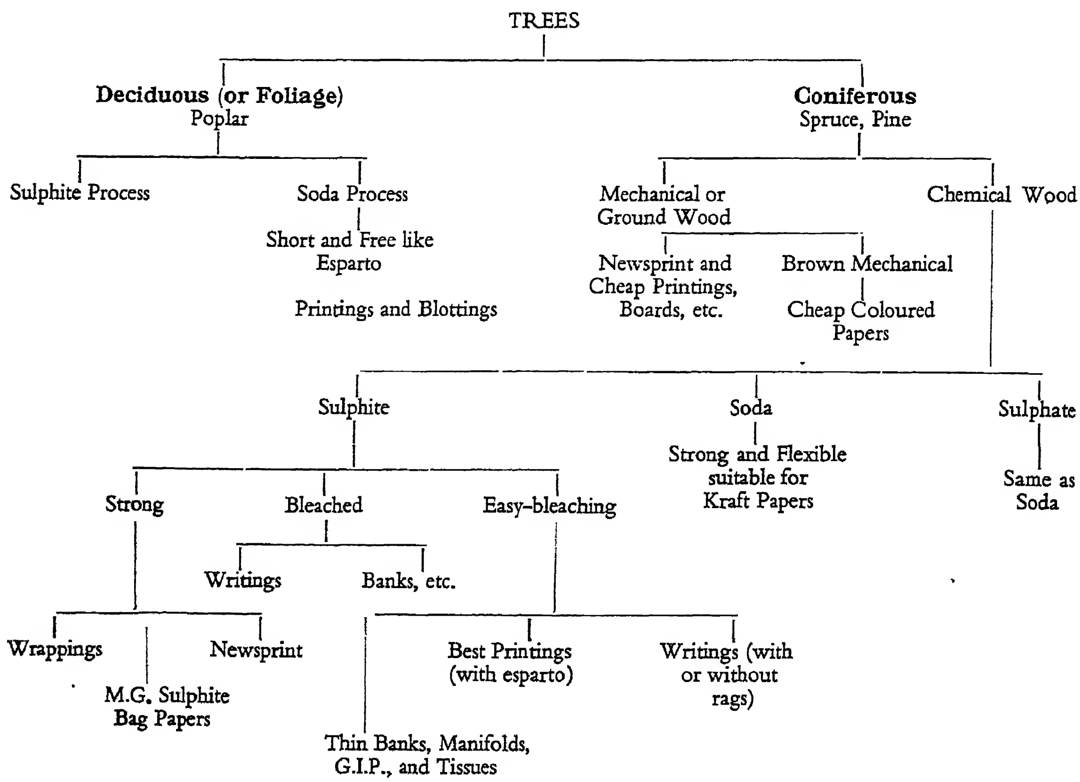
There is also a decided difference in the fibres obtained from the two classes of trees. The fibres from coniferous trees, such as spruce and pine, are longer and stronger than those obtained from deciduous or foliage trees, such as poplar and aspen. The former are more like cotton, and the latter resemble

esparto in that they are short and fine, but they are much flatter than esparto fibres, and do not give such good bulk, for the same finish and substance. When suitably treated (by the soda process) these pulps from poplar wood make fairly good substitutes for esparto, and they are extensively used for the manufacture of better-grade printing papers in America.

The fibres of strong sulphite are used chiefly for giving strength and binding properties to newsprint, and also for the manufacture of strong envelope, bag and wrapping papers.

The fibres of bleached or easy-bleaching sulphites are used alone or in conjunction with esparto in printings and writings, and also with cotton and linen in writings and ledger papers.

From the foregoing remarks it will be gathered that the fibres from trees are of many kinds and have many different uses, which may be roughly tabulated.

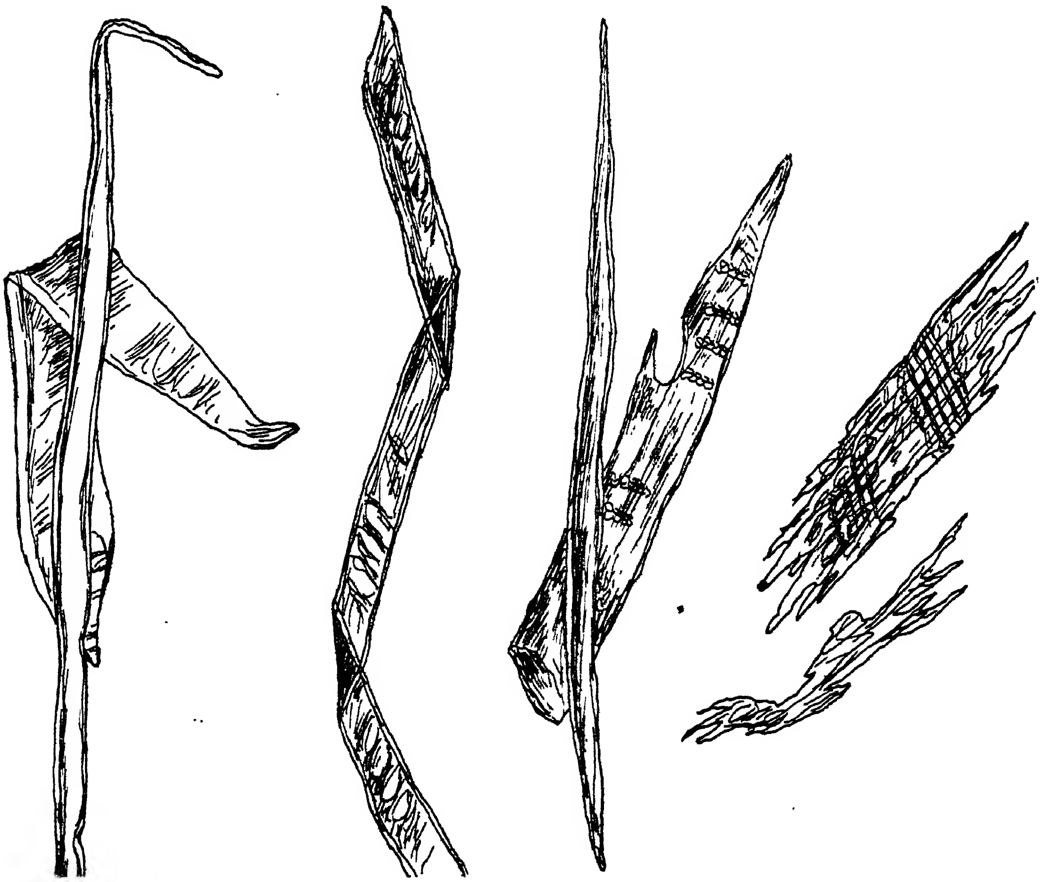


We therefore see that the two classes of trees, treated in different ways, will give us fibres suitable for making practically every kind of paper, from the strongest 'manilla' wrappings to the most brittle and weak newsprint. They will also produce fairly good blotting-paper.

The wood fibres are easily distinguished under the microscope, for mechanical wood fibres can almost always be recognized by the medullary rays or

cross-bindings which can be seen in the diagram (Fig. 2, No. 4). Further, if the fibres are stained with a solution of iodine and zinc chloride they give a bright yellow colour.

Cellulose pulps from coniferous woods consist entirely of fibrous elements (tracheids). The fibres of spring or summer wood are broad, flat and thin-walled, owing to the quicker and more juicy growth of these seasons. Those of autumn growth are thicker-walled and rounded, with pointed ends. The



1. Birch, with cell. 2. Spruce. 3. Poplar, with cell. 4. Mechanical Spruce.

Fig. 2.—The Fibres of Wood Pulp

fibres have circular pores surrounded by depressions, and these are very characteristic, and may be distinctly seen under high magnification (Fig. 2, No. 2). In pinewood cellulose the pores are oval-shaped. Some of the thick-walled fibres are very similar to cotton, and they vary greatly in length.

The fibres of deciduous (foliage) trees (Fig. 2, Nos. 1 and 3) are quite short and rounded, with fairly thick walls, and narrow slits or pores disposed diagonally. Poplar fibres sometimes have nodes, or knots, like linen. The structure does not lend itself to beating or tearing into fibrillæ.

All the juices contained in the fibre cells are boiled out, leaving spaces ready to be filled with water. Very exhaustive research work has been done on wood pulp, so far as its value to the paper-maker is concerned, by the Wood Pulp Evaluation Committee of the Papermakers' Association of Great Britain and Ireland, and the results of their work are contained in a report published by the Technical Section.

Esparto, or Alfa Grass (Fig. 1, No. 3).—The botanical name of esparto grass is *Stipa tenacissima*, meaning 'very strong blade'; Algerian 'Alfa,' Arabic 'Halfa'. This grass grows only in a hot, sunny climate, where the rainfall does not exceed 24 inches annually, and at a high altitude—between 1000 and 4000 feet above sea level. It is a product of Northern Africa, but a superior quality, though less quantity, is grown in Southern Spain. The nature of the soil, altitude and rainfall modify considerably the qualities of esparto. On siliceous soil, the plant fibres are hard and brittle; on sandy soil, they are finer, lighter in colour, longer and stronger; salty earths produce thicker but less tenacious fibres. Iron in the soil accentuates colour. Altitude varies the weight and size of the leaf blade. The heaviest and longest comes from sandy clay alluvia, medium from higher strata, and the lightest and smallest from mountainous regions. The medium is the kind most used by the paper-maker. The longest and heaviest is worked into mats, ropes, etc., and the lightest and finest is best adapted for basket-work.

Green or partially ripened leaves produce the best paper-making fibres. Fully ripened leaves contain more silica and absorbed iron, which resist the action of bleach, and make it difficult to obtain a good white colour. The grass itself is a long, flat blade, curled by the heat of the sun into almost cylindrical shape, with innumerable fine hairs or filaments on its surface. These can easily be felt by drawing a blade slowly through the fingers. When harvested it is not cut, but plucked, and this accounts for the quantity of roots found amongst it. If pulled at the proper time (*i.e.* unripe) the grass comes away more easily, with less roots.

The fibres are distributed through the mass of the blade, together with small fibrous particles, termed cells. These may be serrated, or pear-shaped and pointed. They are of little or no value to the paper-maker, most being lost or washed away in the boiling, washing and bleaching. The pear-shaped cell, however, is peculiar to esparto and forms a sure indication of that fibre when a paper is being examined under the microscope.

The fibres themselves are very fine, cylindrical and smooth, with a minute central canal. Their average length is 1.5 mm. and their diameter 0.012 mm.

Their shortness prevents them from imparting any great strength to paper,

but we have no reason to doubt that esparto papers produced by modern methods are reasonably permanent.

Though esparto may be 'beaten' to a certain extent, the action of the beater roll is confined mainly to brushing or drawing out the fibres, very little 'cutting' being done. Spanish is shorter in the blade than African, smoother in surface, more springy and shows superior strength and colour. It stands treatment better, yielding a whiter and cleaner fibre.

It may be used in thin writings and banks where African would be practically useless. The latter comes to the mill in hydraulic-pressed bales of about 3 cwt. each, and must be stored under cover. Care must be taken to isolate any bales that are wet (which occurs very often to 'deck cargo' during a voyage). These may heat and take fire and should be used immediately if possible.

Spanish is delivered more loosely packed, bound with esparto ropes, and for this reason is less liable to heat and rot. It is usually in a drier condition than African.

Esparto papers are distinguished by their refined silky texture and bulk and close uniform surface or finish. This latter quality is their most outstanding point, and makes them eminently suitable for fine printings and other papers that are required to take a fine impression from plates. The best body papers for surface coating are made mostly from esparto. It is not a fibre that will run well over the machine without a stiffening of wood pulp. Its 'greasy' nature and shortness cause it to stick to the press rolls, causing breaks and waste. A charge that has been too harshly treated in boiling and bleaching soon makes itself known in the machine room. In this connection it has been found that granite press rolls are a very great advantage.

It is a very absorbent fibre, taking up and retaining a great deal of resin size, and may be made into quite a hard, 'tinny' paper, very suitable for E. S. Laid and Wove Writings. The fine surface obtained on some of the cheaper rag papers is due to the small percentage of esparto paper 'broken' used as a filler.

Esparto fibre is very easily water-marked, is very regular in expansion and contraction, and is generally considered the best for making papers that must be accurately and finely printed and cut. For the 'offset' printing process esparto papers are unsurpassed.

A peculiarity of this fibre is that after being beaten ready for the machine it very readily runs into knots or balls, which the strainers (even with 3 to 2½ cut plates) are unable to keep back. These appear as clear spots in a high finish, and utterly spoil the paper, so that if a chest of stuff is affected in the least degree there is nothing to be done but to run it off at the press rolls and re-pulp. This is caused by too much agitation in the stuff chest, either by the agitators being run too quickly, or by the stuff taking too long to work out. The rubbing on

the walls of the chest and the blades of the agitators causes the softened fibres to roll up on themselves, forming little balls.

Esparto very readily absorbs colours, and very brilliant tints may be produced. Though the 'Hollander' beater may be used for this fibre, a lighter type of engine gives better results and is far more economical. The 'Taylor' or 'Tower' beaters with their lighter rolls and separate circulators are very efficient and capable of giving all the treatment that esparto requires.

During the last few years straw has been used in very large quantities by all the esparto mills, owing to the impossibility of obtaining esparto grass consequent upon the war. Many of these mills have made a very great success of straw as a suitable fibre for printing and writing papers, using approximately the same treatment and the same equipment as they previously used for esparto. Owing, however, to the low yield, and the longer time taken in washing, it has not been possible to keep up the same output, and additional plant has had to be installed to enable the mill to keep up production.

The length of the straw fibre is less than that of the esparto fibre, although they resemble each other to some degree. Straw fibres are greater in diameter, and are always associated with the serrated cells characteristic of both kinds of fibre.

It seems possible that many mills, after their experience of the last few years, may continue to use straw even after esparto again becomes available, and this would be very desirable in view of the fact that it is home-produced and gives the farmers a greater return from their cereal crops.

PAPER FROM RAGS

Classes of Rags

Linen and cotton rags constitute the ideal raw material for the production of paper, but on account of their high initial cost they can be used only for the manufacture of papers of the highest class, such as hand-made and machine-made writings, bank-notes, ledger, and filter-papers.

The chief reasons for their suitability and value, for papers of this class, are, that they can be so prepared as to produce papers which are extremely good to write upon, which will stand a great deal of wear and tear, and are probably everlasting.

When rags are properly prepared they will produce a white paper which will keep its colour for hundreds of years without showing any signs of fading or discoloration. The rags in general use may be divided into two classes, new cuttings and old used rags.

New cuttings consist of trimmings and cuttings from textile factories, and are the waste from the cutting out of shirts, shoes, canvas goods and many other articles of clothing, etc. These new cuttings may be divided again into linen and cotton, and below is a list of the various qualities generally met with.

New White Linen (damask) cuttings, obtained from factories making table-cloths and fine linen goods. This is the most expensive form of raw material used in the manufacture of paper, and is used only for the very best thin bank-note papers, which have to combine great strength and durability with lightness in weight. Even in the manufacture of these papers the linen cuttings are seldom used alone, but are blended with cuttings of other materials, such as white cotton.

The designation 'white' serves to distinguish these cuttings from another quality known as 'unbleached'. In the former case the cloth has been bleached white during the course of manufacture, so that it is usually unnecessary for the paper-maker either to boil it with chemicals or to bleach it, when reducing it to half stuff. All that is required, generally, is for the cuttings to be picked over for the removal of dirty pieces, threads or other objectionable materials, which invariably find their way into the bales or bags from the

textile factory. The rags may then be dusted, and boiled to remove any starch or loading which may have been added during the 'finishing' process. If the rags are really good, they may be furnished straight into the breaker or beater.

If after washing and breaking they are of a sufficiently white colour for the paper required to be made from them, they are ready for the beater. If not, they are bleached with bleaching solution until the required degree of whiteness is reached.

New White Cotton Cuttings are almost as valuable material for the manufacture of the best papers as the new white linens, except that they do not give quite such a strong or firm handling paper, and in consequence they are cheaper. The method of preparation of half stuff is generally the same as for linen, though less drastic.

New Unbleached Linen.—This material consists of linen which has been freed from a good deal of the undesirable shive or bark with which it was associated when in the form of flax plant. It comes to the paper-maker in the form of new linen threads, linen canvas cuttings and brown linen cuttings. These are capable of producing papers of great strength, but in order to obtain papers of a good white colour, drastic and prolonged chemical treatment is necessary, and for this reason they are much cheaper than the white cuttings.

The threads or cuttings are first overlooked and, if necessary, cut up by hand; they are then cut and dusted prior to boiling. If they are examined before boiling, they will be found to be of a dark grey or brownish colour, and, on close examination, large quantities of shiny brown or yellow shive or lignocellulose will be seen, closely interwoven with the linen threads.

It is necessary for these impurities to be destroyed before the linen fibres are ready to be made into paper. This is effected by boiling the rags, under pressure, with a high percentage of caustic soda for as long as 10 to 12 hours. The percentage of caustic soda required is sometimes as high as 20 per cent, and the pressure may be from 15 to as much as 45 lb. per square inch.

When the rags are removed from the boiler, they will be found to be very much softened, to have lost a good deal of their grey or brown colour, and the particles of shive will be seen to be softer, and lighter in colour.

The rags are now washed with water and bleached with a bleaching solution. If, when the bulk of the fibres has turned almost white, a handful is removed from the breaker, it will be seen that the shive is still present, although paler in colour. In order to destroy it further, dilute hydrochloric or sulphuric acid may be added in small quantities. This causes the formation of hypochlorous acid, which attacks and destroys the brown or yellow colour of the shive. This shive or lignocellulose may also be destroyed by subjecting the

half stuff to treatment with chlorine gas in a gas chamber, but it is better, if possible, to remove it subsequently by mechanical means in a centrifugal machine.

In order to obtain half stuff of a good colour from such linen or flax, and also as free as possible from shive, it will generally be found advantageous to use more caustic soda in the boiling, and subsequently less bleach, than *vice versa*, as by this means the rags are not so liable to become tender. Such stock can rarely, if ever, be bleached to such a good white colour as cotton.

New Unbleached Cotton Cuttings, sometimes known as 'new greys' or 'yellow cottons', are the waste from factories using unbleached calico, and they vary greatly in quality and value. The best 'board cuttings' are usually excellent material, containing little or no loading or starch, and being free from shive and dirt. They are often nearly as expensive as new white cuttings.

On the other hand, new greys may consist of shoe cuttings or the waste from shoe factories, consisting of inside linings of leather shoes and trimmings from canvas shoes, and 'Swansdown'. While some of this material is excellent and equal to new board cuttings, a great deal of it is coarsely woven and full of loading. The loading in some cases is as high as 70 per cent of the weight of the rag. This loading is, however, by no means the greatest drawback to this material; leather dust and small clippings of leather, and, above all, rubber solution, so difficult to detect in the rag room, make the use of it very risky indeed.

Unbleached cottons are picked over by sorters, and the long strips are either cut up by hand into suitable lengths, or the whole may be put through the chopper and dusted prior to boiling.

Caustic soda is used for boiling, the amount varying according to the quality of the rags, and the amount of starch and loading which they contain. From 2 to 5 per cent of caustic soda will generally be sufficient, when the pressure employed is about 25 lb. and the length of boil about 6 hours.

New Lace Curtain Cuttings are a valuable material, being strong, clean and easily prepared. Their chief drawbacks are the amount of starch which they contain, and also the small hard knots, which have to be carefully broken up.

They require to be overlooked, on account of floor sweepings from the factories, which sometimes find their way into the bales and introduce chips of wood, straw, etc. A small amount of soda ash (sodium carbonate) is usually sufficient to reduce them during boiling, which may be completed in 3 or 4 hours. They require careful handling in the breakers and very little bleach.

New Unbleached and White Cotton Healds can sometimes be obtained, and they form a valuable substitute for new 'greys'. These consist of cotton strings about 6 to 12 inches long, plaited together at one end. Those from Egyptian cotton are best, and they give a pulp of great strength and cleanliness.

They are usually very free from foreign matter; they require gentle treatment in the boiler, being almost pure cotton; and apart from the hard strip of twisted strings at one end, they are easily broken in, but they must first be cut up small by hand.

New Oxfords and New Light Prints are the cuttings from shirt and dress factories, and at one time they were an important raw material for the better classes of rag papers where strength was required. Nowadays, however, some paper-makers are inclined to view them with suspicion, on account of the so-called 'fadeless' dyes used in forming the stripes and designs on the material. Although these dyes can generally be removed by the usual methods of treatment in the boiler and breaker, yet there is no doubt that some of them are very tenacious and require fairly drastic treatment, both in the boiler and more especially during bleaching, if all the dye is to be removed. Some mauves, yellows and blues are particularly hard to bleach out, and even when the blues are removed from the material in which they were originally fixed, they seem to pervade the whole mass of half stuff and give it a bluish tinge. Of course, if the oxidizing treatment is sufficiently drastic, the whole of the colour can be destroyed, especially if chlorine gas is used, but it then becomes questionable whether this has not led to such tendering of the half stuff as to render the material too expensive compared with the results obtained.

There are many other new rags which might be described in detail, but the foregoing is a fairly comprehensive list.

Among others may be mentioned flannelettes, which are cotton cuttings; 'tab-ends', or the ends of new pieces of cotton goods; linen threads, cotton canvas cuttings, new blue jeans, etc.

We now come to the second class of rag material—namely, used or old rags. These rags differ essentially from new rags in that they are very mixed in quality, no matter from what source they are obtained, and they are always dirty—the only difference between one lot and another being in degree. They are, on the whole, much softer and incapable of yielding a half stuff of such strength as that obtained from new rags. They contain contraries and impurities of all kinds, all of which have to be removed by the paper-maker.

Taking the used rags in order of 'quality', clean white linens and cottons come first.

No. 1 Linens consist of such articles of domestic use as tablecloths, pillow-cases, sheets, handkerchiefs and clothing of all kinds. They are only fragments of the original article and are fairly clean and free from impurities.

They require to be overlooked and cut up, prior to boiling, for the removal of buttons, elastic, etc. They also require gentle treatment in the boiler and

breaker, and yield a pure and clean half stuff of good strength, which will become easily fibrillated and give a firm handle to the paper.

No. 1 *Fines*, or *Best Fines*, consist usually of a mixture of linen and cotton. They are always white and clean and of fairly good strength—that is, they are not absolutely worn out. They consist of much the same classes of articles of domestic use as the No. 1 Linens, and often include collars and cuffs, white shirts, etc. When of good quality they are heavy rags, and contain many large pieces and few strips. They must be overlooked for buttons, fasteners and elastic, and they are cut up by hand prior to being put through the chopper.

They are boiled with a very little caustic soda—say, 1 per cent—or a little soda ash is often sufficient. The pressure used need not be high and the boiling need only last for 2 to 4 hours at most. They require very little bleach, and give a beautiful pure and clean half stuff, which can be beaten off very quickly without getting too wet.

These rags are used chiefly for the manufacture of superfine writing papers which have to be pure and bright and 'pretty'.

Outshots and Second Fines are the same as the previous quality, but are not so clean, or so large in size, and are more worn out. They are, in fact, thrown out by the rag sorters when grading for Best Fines. They need to be carefully overhauled for buttons and fasteners, elastic and 'dress preservers' which contain hidden rubber solution. They often contain a great many strips of clothing which have rows of buttons and minute metal fasteners attached.

They need more caustic soda and longer boiling than Fines. They give a fairly bright white half stuff, but it has not the strength of the Fines, and they need more bleach.

These rags vary a good deal according to the source of supply, and great care must be exercised in the buying of them.

Soiled Curtains.—These are often packed separately, although they are also included among outshots and seconds. They are a soft cotton rag, very often tender on account of frequent washing and exposure to light and air when hanging in windows. They are, however, very uniform in quality. They require to be carefully sorted to remove pins and elastic and metal rings. They require little caustic, gentle boiling, and very little bleach. When carefully handled they give a much stronger half stuff than would be expected, considering how easily they tear before treatment.

They can be made to give a very free working stuff, suitable for blottings and filterings.

Seconds.—There can surely be no class of raw material used by any manufacturer which varies so much in quality and price as 'Seconds'. All rag merchants sort and pack them in vast quantities, but no two merchants sort to

the same standard, and for this reason the task of the rag-sorting department of the mill is made extremely difficult.

It is impossible to give even a general definition of Seconds to cover the whole of the packings of rags sold as such. Suffice it to say that they are all supposed to be derived from cotton, and they consist of clothing of all kinds, from tropical suits to imitation woollen underclothing, and from bed-ticking to dishcloths. Every imaginable article of textile manufacture is included among them, and in colour they range from one end of the spectrum to the other, with the addition of black and white. So much for the rags themselves.

If the trouble ended here the task of the paper-maker would be comparatively easy. It is, however, in the matter of contraries that a great deal of trouble arises, and by contraries is meant the 'mulch' or useless material which is often included in large quantities. It is quite impossible to refer to these in detail, as their name is legion, but a few of the commonest may be mentioned. These are silks and wool, string, bones, orange-peel, whalebone, feathers, horsehair, rubber, straw, etc.

Even in the best packings a certain quantity of these is always present, and it is simply amazing to see the amount of rubbish which is thrown out of what appears at first sight to be a fairly decent lot.

There is only one basis on which these rags may be bought with satisfaction, and that is on a pre-arranged standard of percentage of 'mulch', any excess over the agreed maximum percentage being debited to the seller, or returned to him after the parcel has been overhauled.

In fairness to the merchants, however, it must be admitted that there are some who grade their rags regularly within close limits, and these packings can always be relied upon to contain a maximum of about 5 per cent of 'mulch', and very often much less. These rags are, of course, much more expensive than the ordinary run of so-called Seconds, but by the time they are converted into half stuff they will be found to be considerably cheaper, and what is of as much importance to the paper-maker, they will yield a much more uniform stock.

Seconds are always divided into several grades, such as Country Seconds, which are the largest and best; Selected Seconds, which are usually fairly clean and free from dark colours; and London Seconds, which are invariably dirty, 'strippy' and generally poor, worn out and often actually rotten.

In judging Seconds it is quite useless to depend on a post sample; at least a ton must be bought and carefully sorted before any real estimate can be made of their value.

There are many different things which must be taken into consideration when estimating their value, some of which may be given in detail:

(*a*) The general colour of the consignment must be taken into account, as on this will depend the amount of caustic soda and bleach required to bring the half stuff to a sufficiently good colour. The more caustic soda and bleach required, the more 'tender' will be the resulting half stuff.

(*b*) The amount of 'mulch' which will have to be thrown out as useless, such as silks, wool, etc. A large quantity of these contraries will reduce the ultimate yield of cellulose.

(*c*) The 'weight' of rag—that is, the weight of a given bulk—determines in a rough way the ultimate strength of the fibre, or, in other words, shows whether the rags have been well worn or not. Naturally, rags which have not been much worn or washed will yield a stronger and harder fibre than those which have been well worn and often washed.

(*d*) The general size of rag is also very important. When the pieces are large they are quickly sorted, and when the garments are fairly complete the sorters find it much more easy to discover the buttons and fasteners. On the other hand, when the rags are strippy and contain large quantities of small pieces, such as the fronts of shirts, cuffs, seams, etc., they take much longer to overlook, and the chances are that many more buttons, metal fasteners and pieces of elastic are missed, and ultimately find their way into the half stuff.

With Seconds, the amount of caustic soda and the length of boiling vary greatly, and in order to keep these regular, or within reasonable limits, the rags must be sorted to a uniform standard in the rag loft, and this should be regularly checked. If insufficient caustic or too short boiling is given, the fact will soon reveal itself in the breakers, as the bleaching will require to be more drastic and some of the colours will be difficult to destroy.

If, on the other hand, more caustic has been used than is necessary, it may not be noticed, but it will certainly cause the half stuff to be very soft and tender, and strength will have been unnecessarily wasted.

There is another grade of soft coloured rags sorted and sold as distinct from Seconds. These are called Prints, or more usually Old Light Prints, or Extra Light Prints, and they consist of much the same kind of material as Seconds, except that they are mostly 'printed' cotton, as distinct from the white and coloured rags of Seconds.

These rags are often stronger than Seconds, and they frequently cost a little more, but they require more drastic treatment to remove the colours, many of which are nearly unfadable nowadays, and bring up the colour of the half stuff.

The aforementioned constitute the most important grades of old soft rags in general use.

Mention must be made of the several grades of Continental rags, which find their way in large quantities into the stores of the rag merchants of this country, and are sometimes used to 'adulterate' the home-produced article.

These consist for the most part of white cottons of several grades, which correspond roughly in order of precedence to English second fines, outshots and white seconds. They are less clean, less consistent in quality, less strong, and they invariably contain more rubber than the English grades, and they are consequently less expensive in first cost.

Old Light Prints are imported in large quantities, but the packings vary considerably, even from the same source, and are less dependable even than the English grades.

Unfortunately, these prints are frequently mixed with home-produced rags, and almost always they reduce the general quality of the consignment.

Continental white linen rags are, however, of great value, and form an important raw material. They are composed chiefly of home-spun clothing of a grey colour, always well worn, and varying in coarseness of texture from rough 'sacking' to a fine linen cloth.

The chief trouble encountered with these rags is shive, or the outer bark of the flax plant, which has not been properly removed in the 'retting' process. The presence of a large quantity of this reduces the value of the rags so far as strength is concerned—and it is for strength that they are used—as it means more caustic soda and more prolonged boiling than would otherwise be required.

Nevertheless, these linens are often a welcome addition to the furnish on account of the great scarcity and consequent high price of English linens.

General.—The quality of rags obtained in any district reflects to a remarkable degree the prosperity or general habits of the inhabitants. Rags from prosperous seaside towns, or fashionable health resorts, are always far superior to those from poor industrial areas. Scotch rags are generally better than English rags, and country rags are cleaner than those collected in London and other large cities.

Old Strong Rags.—These consist of linens and cotton canvas in various forms, and the consignments contain a mixture of each.

Linen sail-cloths from the seaports are, as a rule, in large and often unwieldy pieces, difficult for the women to cut up into strips. They are very hard, contain many 'eyes', often lined with metal rings, are covered with tar, pitch and paint, and have hard edges bound tightly with tarred string. The contraries consist chiefly of those things mentioned above, which have to be cut out.

This canvas requires a high percentage of caustic soda and prolonged

boiling, but it yields a strong and tough half stuff suitable for making strong thin papers.

Hose canvas, both cotton and linen, is obtained from the dockyards and from municipal authorities. It is clean, usually almost new and little used, and nowadays rarely contains rubber as insertion. It is cut up into short strips before boiling, and gives a strong clean half stuff of excellent colour.

Cotton tentage yields a useful strong half stuff of good colour. It is fairly reliable in quality and contains few contraries beyond metal hooks and eyes.

It is usually clean and white, although it is sometimes covered with water paint, which is easily removed. It requires a comparatively small amount of caustic soda, not very drastic boiling, and gives a strong white half stuff.

Linen canvas consists of a mixture of all kinds of linen from post office bags to tarpaulins and sailors' hammocks. It is usually greasy and contains varying amounts of shive, to remove which it requires a large percentage of caustic soda and prolonged boiling.

It gives a 'greasy' and easily fibrillated half stuff, which cannot be bleached to such a white colour as cotton canvas.

Cotton canvas is packed in various grades from No. 1 downwards. The best grades are white, clean and free from contraries. They do not require such severe treatment as linen canvas, and they produce a pure and white half stuff, which gives hardness and strength to the paper. They contain a good percentage of fairly new canvas. The lower grades contain all manner of coloured pieces, from 'Willesden' green to brown tanned, and they are always dirty, covered with paint, soot, tar and grease. They contain metal hooks and eyes, buckles and rings.

This material is very difficult to sort, as it is always questionable what to throw out and what to leave in, owing to the uncertainty of the action of the lime, caustic soda, etc., on the various substances coating the canvas. It is always best to throw out anything about which a doubt exists—at least until a test has been made in the laboratory—as it is most annoying, and indeed wasteful, to have a whole boiling spoilt by allowing a few pieces of stuff to pass when there is any question as to its suitability.

One of the worst evils of this material, and one of the most difficult to detect, is rubber, either sewn or woven into the canvas, or coated on to it in the form of waterproofing solution, and many a good boiling has been spoilt by this troublesome bugbear of the paper-maker.

Hemp, manilla, jute ropes and bagging are used in the manufacture, both of the highest and purest, and also of the lowest grades of paper.

Ropes and bagging are used for making wrappers. Hemp and manilla ropes come to the mill in thicknesses varying from quite thin rope to 12-inch

hawsers, which entail a lot of heavy work in handling and preliminary treatment. The largest ropes are cut up with felling axes, and then divided into the smaller component strands, which are in themselves thick ropes; they are then cut up by means of a mechanical rope chopper, of which there are several varieties. The simplest form consists of a machine similar to a chaff-cutter, which shaves off the rope into pieces of suitable length ready for the boiler.

There are not many contraries contained in ropes, but 'shakes' are often included, and these consist of frayed ends and small rough pieces which contain dirt or dust.

The boiling of this material is far more drastic and prolonged than that of any of the canvas previously referred to. Tarred hemp ropes and coal sacks are often boiled several times with a high percentage of reducing agent, and subsequently they are bleached and allowed to drain, and then bleached again.

This treatment results in the production of a strong, tough, flexible half stuff of a pure white colour combined with great opacity.

Manilla rope stock is prepared in the same way as hemp, except that the treatment in the boiler is less drastic, as a white half stuff is not usually desired nor is it easily obtained. The shive is very difficult to remove, but the half stuff is very soft, flexible and silky, and capable of producing papers of enormous strength and toughness—some, in fact, are almost untearable.

Jute cuttings, various strings, jute bagging, etc., are used for the manufacture of brown wrapping papers, but very little chemical treatment is necessary, as the papers to be made are very coarse and their colour is of comparatively little importance. Lime is used in the boiling of such material to remove grease and other objectionable matter.

Of course these materials may be resolved to a very pure cellulose, if required, by using caustic soda and employing high pressures, and by using chlorine gas as the bleaching agent, afterwards removing the chlorination compounds by washing. The yield, however, is much reduced, and the strength of the fibre much impaired in the process.

CHAPTER III

TREATMENT OF RAGS

Sorting—Boiling—Washing—Bleaching

After the rags have been received into the mill they are carefully examined to see that they are up to sample as regards colour and quality, in order that the attention of the supplier may be called should the delivery appear to be below the standard. A few bags or bales are opened, and thus a general impression of the quality of the consignment is obtained. Should the rags be below the standard of the sample, they are left on one side until the supplier has been communicated with and given an opportunity of inspecting them. If the rags seem all right, they are put into stock ready for use.

Before the rags pass into the rag loft to be overlooked they are passed through a conical duster to remove grit, dust, and any loose dirt, buttons, etc. If this method is adopted it makes the task of the women overhaulers much more pleasant, and the rag loft is also rendered more free from dust.

When the rags have been rough-dusted they are passed to the rag loft to be overhauled and examined by women. The rag loft consists of a large room equipped with rows of sorting tables, having coarse-mesh wire tops and fitted with large vertical fixed knives opposite each sorter, so that the large pieces may be cut up and buttons, etc., removed. A vacuum pump must be installed to draw away the dust from under the wire mesh. This also helps to give a purer atmosphere to the room.

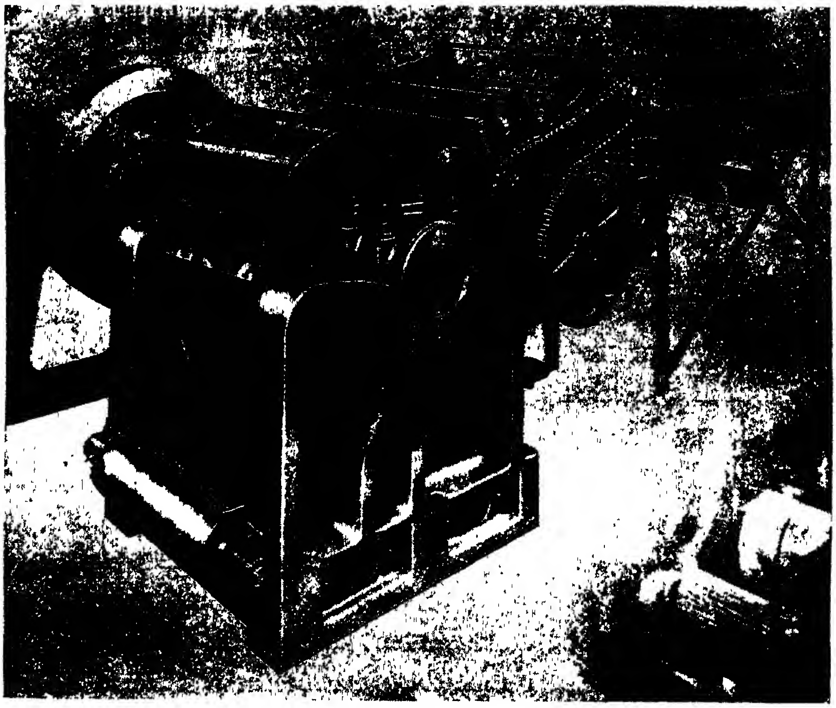
The task of the rag sorter requires a great deal of experience and skill, as the rags often have to be graded into one or two or even more grades, and also contraries in the form of silks, wool, etc., have to be thrown out. It is also imperative that all rubber, whether in the form of elastic, solution or insertion, should be carefully picked out, as it is without a doubt the worst enemy of the paper-maker, and it is amazing to see the different ways in which rubber in one form or another is used in clothing, and how it is concealed.

Next in importance to rubber come the buttons, hooks and eyes and metal fasteners of all descriptions which are used on clothing. These are sewn in all sorts of unexpected places, and the greatest care and patience is required on the part of the women if they are to free the rags thoroughly from them. Any carelessness on the part of one woman may spoil the work of twenty, as if the buttons or fasteners get through and into the boilers, they have only the 'button

catchers' on the breakers to deal with them, and although these are in many cases quite efficient, they cannot catch everything.

If there is serious trouble in the mill from metal or rubber in the paper, the rag loft is the root of the evil—it must be tackled there. Skilful supervision and, above all, great tact are required in the management of the rag loft if the best results are to be obtained.

It is usual for the overhaulers to be paid piece rates for sorting the rags, the rates varying according to whether the rags are fines, seconds, canvas or



[*Masson, Scott & Co., Ltd.*

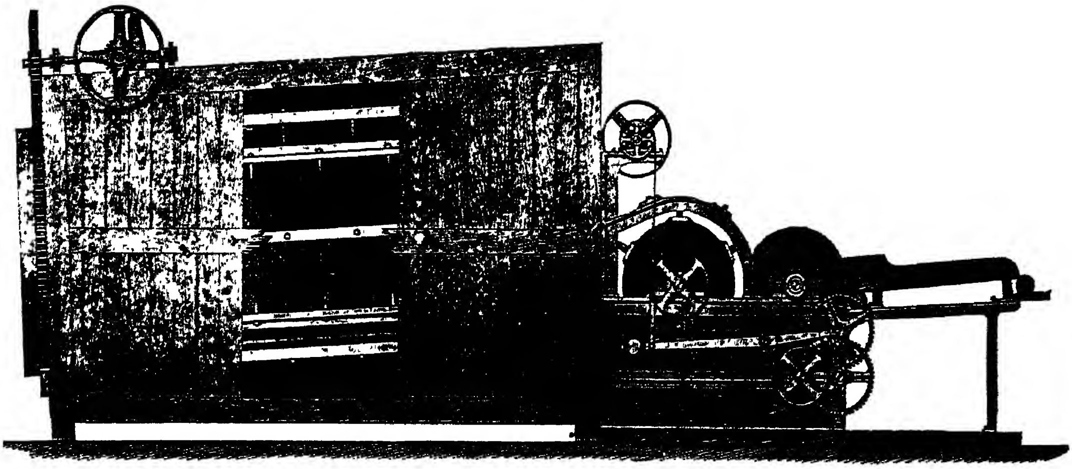
Fig. 3.—Latest Type Giant Heavy Rag Chopper

new cuttings, etc. After the rags have been overhauled, they are either bagged up or stored in bins until required, and they are then overlooked again by other women—paid daily wages—whose duty it is to run the rags through and pick out anything in the way of contraries or buttons and rubber which may have been missed by the sorters.

The rag loft should be light and airy, and the women should have comfortable and convenient tables to work at, and they should also have a proper arrangement of boxes or bags into which the separate grades may be sorted. They should also be provided with boxes for rubber, buttons and contraries. It is usual to pay the sorters extra for all the rubber and buttons which they pick out, and these are weighed separately for each woman periodically and paid for at an agreed rate.

Great economy and efficiency may be introduced into the rag loft by the use of a little care and thought, and by the provision of suitable and convenient tables and appliances. In one case, the number of women employed was 80 for the sorting of about 52 tons of rags of various grades per week. By reorganizing the rag loft and providing convenient tables and receptacles, the number of women was reduced to 30, and the same amount of rags was passed through and dealt with far more thoroughly. Of these 30 women, only 16 were actually employed on overhauling the rags.

When the rags have been sorted they are ready to be cut up into pieces of convenient size for the boilers and breakers. Formerly the rags were all hand-cut by the women, but nowadays this slow method has been superseded by



[*Bertrams Ltd.*

FIG. 4.—RAG WILLOW AND DUSTER, WITH PART OF COVER REMOVED TO SHOW WIRE-COVERED DRUM AND SPIKES

the rag chopper. There are several types of machines in use, but they all work on the same principle. The rags are fed into the machine along a travelling band, and pass first between 'ripping' wheels, which cut them up lengthways into strips. They then pass between a heavy revolving knife and a dead knife, and the strips are cut off into short square pieces. These machines are very efficient and will cut up anything from fine muslin to stout canvas with equal facility. After the rags leave the chopper they are carried to a willow, where they are tossed about and opened up, and they then pass to a conical rag duster.

The rag duster (Fig. 4) consists of a kind of hollow tapering cone made of iron or wooden bars securely bolted to circular metal ends. The bars are fitted with iron spikes about 6 or 8 inches long, which project into the inside of the cone, and serve to lift up the rags from the bottom as the cone revolves, and drop them down again on to the sides, which consist of coarse mesh wire

cloth. This action loosens extraneous matter such as dust and dirt, and most of it falls through the meshes of the wire cloth on to the floor below, from which it is cleaned out at convenient intervals, or it may be sucked out by a fan and blown into water.

The whole duster is enclosed in a dust-proof wooden box, the front side of which may be removed for cleaning purposes. The cone is supported on four wheels, on which it rides, with a steel band or tyre fixed to each end of the cone to coincide with the wheels. In addition, there is a toothed wheel bolted to the cone at one end, and this engages with a small pinion which transmits the drive from the motor or shaft pulley.

The rags are fed in at the small end, and travel slowly down towards the large end, from which they are discharged into suitable receptacles or on to a travelling band.

After the rags have passed through the duster they may be again overlooked by women, to remove buttons and other contraries which may have been missed. This is best accomplished by having a travelling band about 3 feet in width to carry the rags along after they leave the duster. The women stand on either side of the band and examine the rags as they pass.

Rag Boiling

It is necessary now to boil the rags with water under pressure, and in most cases to assist the reducing action by means of caustic soda, soda ash or lime, or sometimes by a combination of two of those chemicals.

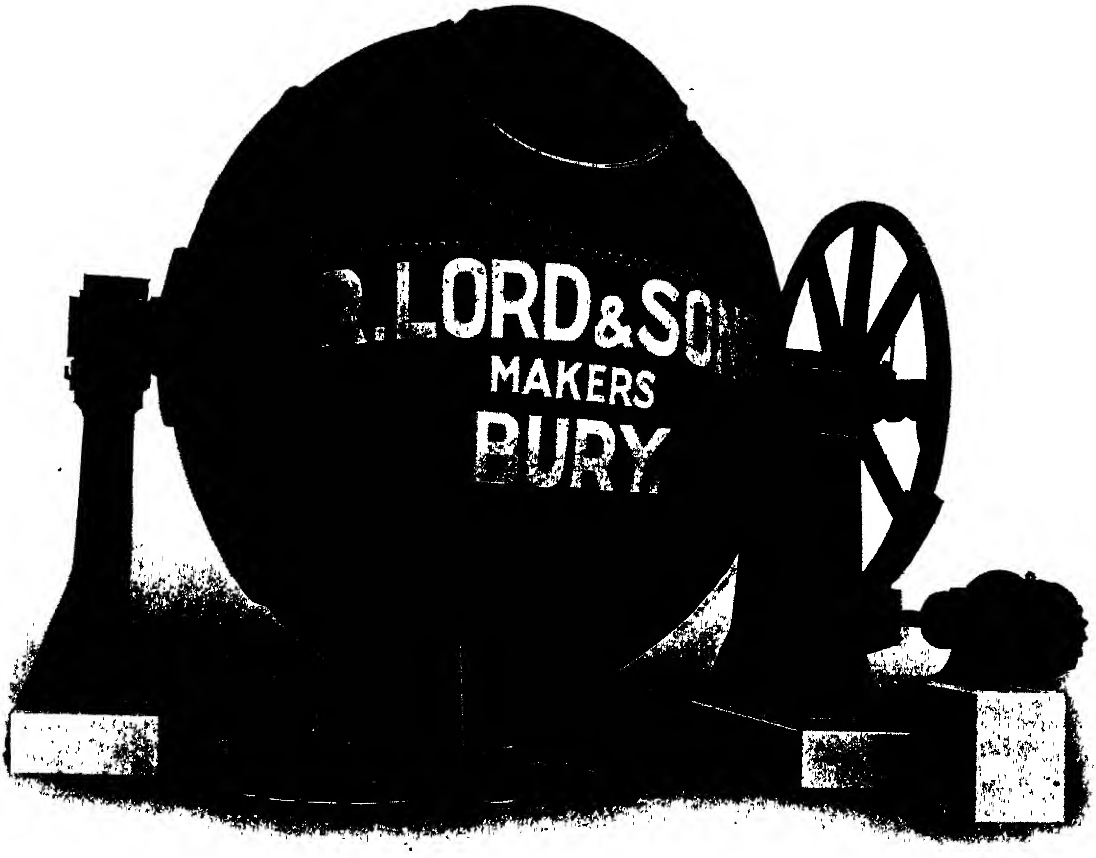
The boiling is usually carried out in spherical or cylindrical revolving boilers (Fig. 5), and in our opinion the best form is the spherical type, on account of the ease with which it may be filled and emptied. While a spherical boiler may be filled by one man, and almost empties itself, a cylindrical boiler, even if it has two manholes, nearly always needs to be packed, and this necessitates the men entering it, and it also takes much more time and labour to empty.

The boiler is first filled with the required amount of water, and the rags are then put in. When the charge is complete the caustic soda liquor or soda ash is added, the lid bolted on and the steam turned on.

The caustic soda to be used should be broken up and weighed, and then dissolved in hot water, or a supply of the solution may be kept at the proper density, and a known number of gallons can then be run into the boiler.

It is necessary that great care should be taken to ascertain the exact amount of caustic soda which is being used for each boil, as otherwise endless trouble will arise through too much or too little being used and the boil being spoilt.

The steam pressure varies according to local conditions, such as the boiling capacity of the mill, the nature of the rags, etc., but it can be taken as established that a long boil at a low temperature gives better results than a quick and drastic boil at very high pressure and temperature. For all ordinary grades of rags 20 to 25 lb. to the square inch is sufficient, and recording steam pressure and temperature meters should be installed, so that the actual pressures and



[*Messrs. R. Lord and Sons, Bury*

FIG. 5.—SPHERICAL RAG BOILER, HOLDING UP TO SIX TONS; FITTED WITH LARGE MANHOLE TO EMPTY IN ONE OR TWO REVOLUTIONS

temperatures being used can be seen at any time. Thermostats are now available for controlling the latter.

As soon as the pressure reaches the required level, the steam should be turned off, and no more allowed in so long as the pressure keeps up. Reducing valves and safety valves must, of course, always be fitted to prevent dangerous pressures from being reached. The action of the alkalis on the rags is to remove grease, which is always present in rags, and to convert it into soluble soaps, which are washed out in the washing water. The alkali also removes a great deal of colouring matter, starch, size and other impurities.

When lime is used instead of caustic soda or soda ash, there is the risk of the formation of insoluble compounds, and the rags are often hardened; nevertheless, in some mills where the washing water is very soft, the addition of lime seems to be absolutely imperative, otherwise it is impossible to get rid of all the grease, and it is found coating the sides of the breaker. In other mills where the water is very hard the use of caustic soda together with soda ash gives the best results in practice.

Below is a table of the amounts of caustic soda and alkali used on various qualities of rags where the pressure employed was 25 lb. per square inch. The amounts were arrived at after long and careful trials, but of course they were not always strictly adhered to; the quality of the rags in each boil was always taken into account, and slight alterations were made both in the quantities of alkali and the number of hours of boiling. No more water than is necessary to prevent the rags being 'burned' should be used, as the more concentrated the alkali solution the more economical will the boiling be.

Boiling Details for a 1-Ton Boiler dealing with Rags for the Highest Grades of Writing Papers

(Pressure 25 lb. per square inch. Hot water washed)

	Hours of Boil	*Caustic Soda (Lb.)*	*Soda Ash (Lb.)*
Fines, ordinary	4–5	25	28
Muslins, clean	4	—	28
„ soiled	5	—	56
New unbleached calico ('greys')	5	25	—
New white cuttings (second quality)	3–4	—	12
New lace cuttings	4	—	12
Seconds, dirty white (outshots)	6	50	28
„ light	8	100	56
„ low quality	8	125	56
Old light prints, good	7	100	28
„ „ low	8	125	56
Cotton canvas	10	125	56
Linen canvas	10	250–300	112
French linens	8	250	112
Cords, light	10	125	56
Ticking, linings, etc.	10	150	56
Cotton healds	6	50	—
White cotton tents	7	100	28
Filter-cloths	8	100–200	56–112
Old white linens	6	75	56

When the boil is complete the boiler is blown off, and the dirty water containing the dissolved grease, etc., is run away to the sewer or other convenient place, unless the soda is to be recovered. The boiler is then filled up with hot

water and rotated for a further period of about an hour. This washing water is then run off, and the rags are ready to be emptied. It is advantageous if they are then put through a conical washer of the same construction as the duster already described. This washer rotates in running water, which carries away more dirt and the remains of caustic soda, and greatly reduces the time of the final washing in the rag breaker. The rags are emptied from this washer into boxes on wheels and are ready to be taken to the rag breakers.

Rag Breaking

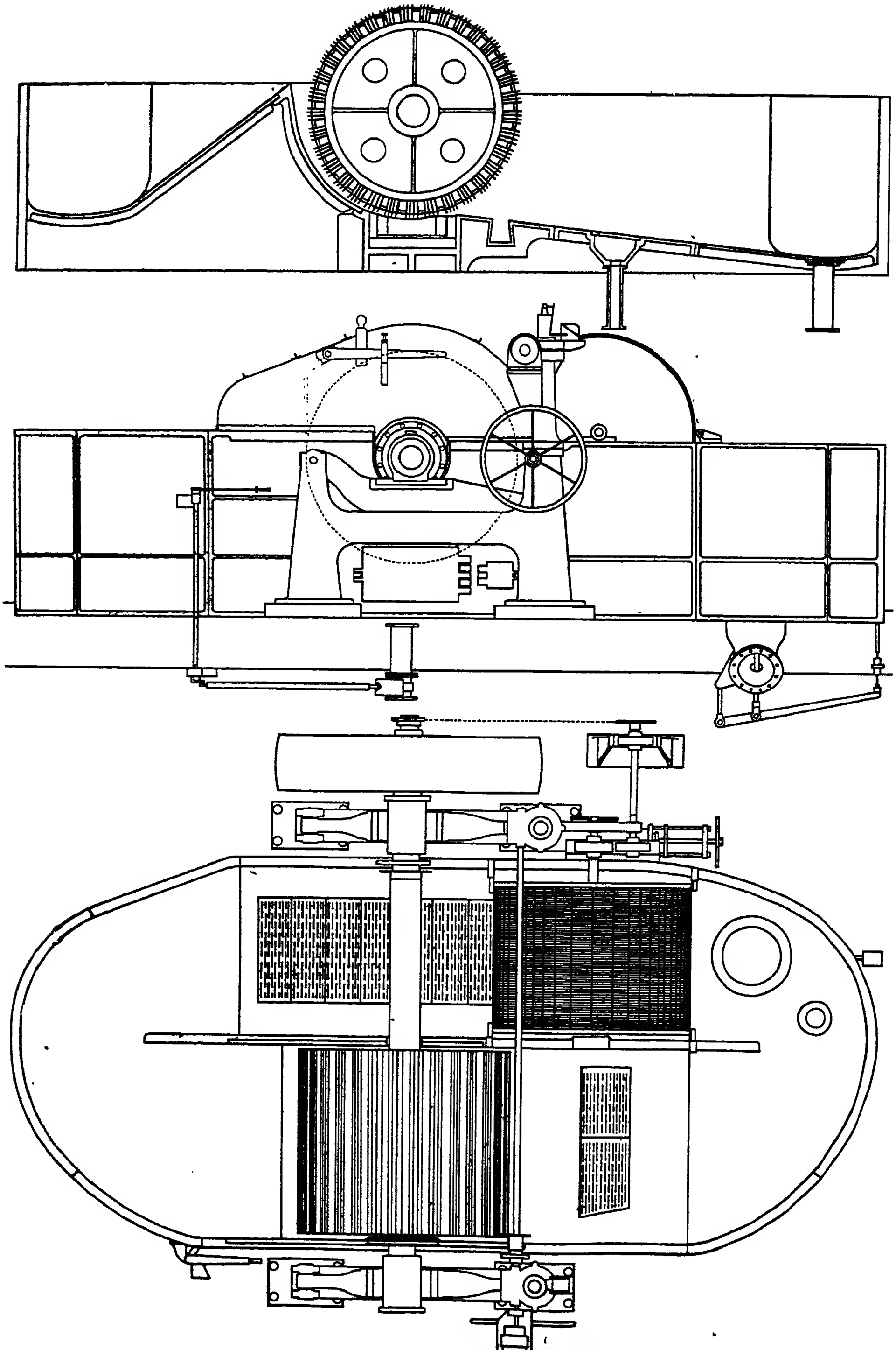
The rag breaker (Figs. 6 and 7) consists of an engine of exactly the same design as a Hollander beater, except that it is always fitted with a washing arrangement, and also contains a sand and button catcher. It has a bed plate and roll, which can be raised or lowered. The sand catcher is formed by having a portion of the bottom of the trough, along the midfeather and opposite the roll, cut away, or cast below the general level of the trough. This cavity is about 4 or 5 feet long by 18 inches broad, and is covered with a perforated or slotted plate.

The idea is that the sand and any heavy particles will sink to the bottom of the trough and fall through the perforations of the plate, and thus disappear below the level of the stuff and remain there until cleaned out after the rags have been let down.

The button catcher is on the same principle, except that it is placed immediately in front of the roll, and instead of a perforated plate it has a slotted plate, so that the buttons, safety-pins, etc., may slip through sideways on.

Some breakers do not have these somewhat elaborate arrangements, but depend simply on a narrow channel cut in the bottom of the trough, about 1½ inches deep by 1½ inches wide, and extending from the corner of the midfeather to the side of the trough. The washing is accomplished in two ways. The first method is to have one or two drum washers, which may be raised or lowered into the stuff at will by means of a worm wheel and pinion. These washers are placed above the trough, as shown in the illustration (Fig. 7), and they consist of a hollow drum, covered with perforated honeycomb bronze plates, which are again covered with fine-mesh wire cloth. Inside the drum is a bucket-lifting arrangement for catching the dirty water which comes through the wire mesh, and for conveying it through one end into a trough which carries it away to the drain. A later drum washer has one open side connected to a pipe in the side of the trough.

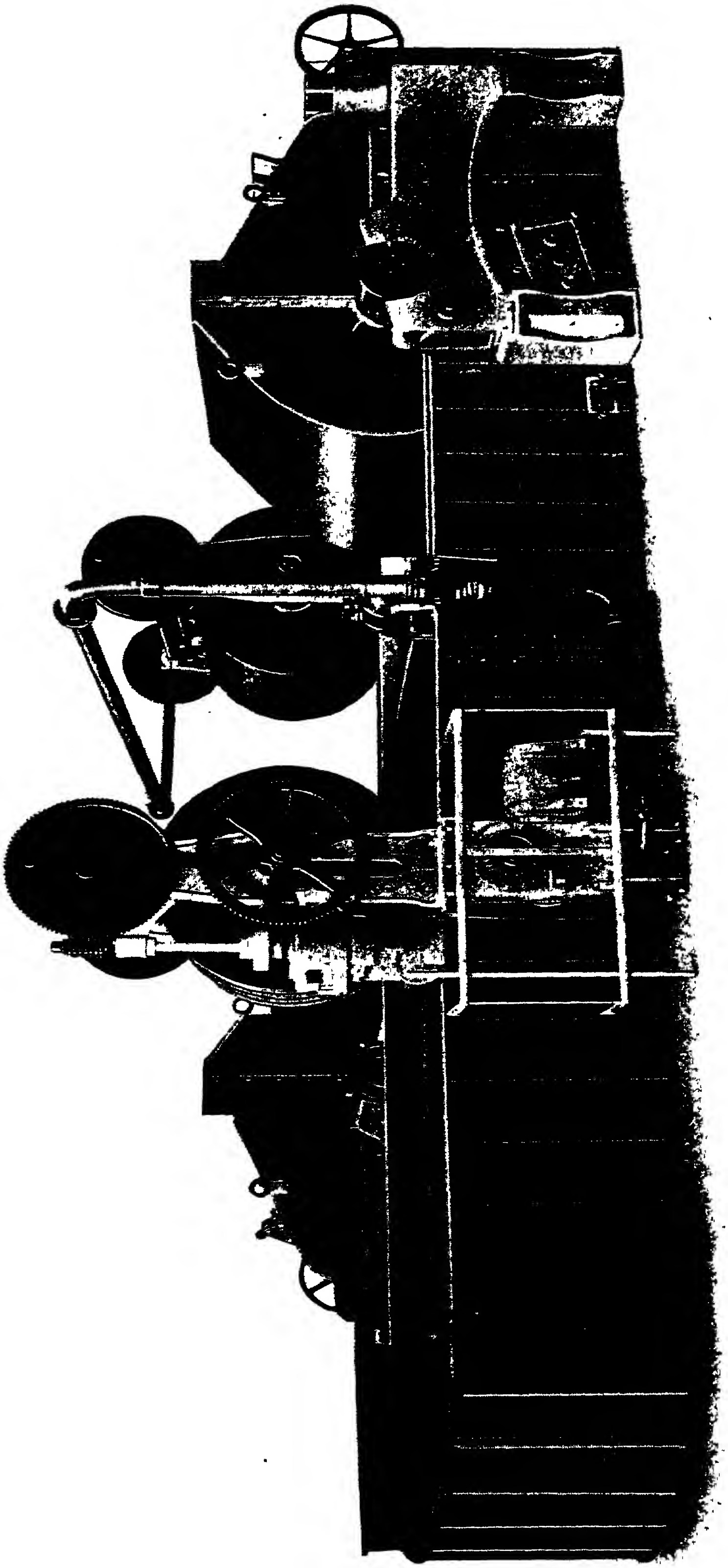
The second method, which may be used either alone or in conjunction with



[*Messrs. Bentley and Jackson*

FIG. 6.—LATEST TYPE HEAVY DUTY RAG BREAKING AND WASHING ENGINE

Fitted with 10-ton roll and rapid washing extractor drum. Holding 1 ton of rags and having trough designed for rapid circulation.



[James Bertram and Sons Ltd.

FIG. 7.—LATEST TYPE HIGH CAPACITY RAG BREAKING AND WASHING ENGINE, WITH TWO EXTRACTOR DRUMS AND INTERNALLY DRIVEN ROLLS

the drum washer, consists in having a wooden cover placed on the roll, and fitted with slots at each side, into which fit frames covered with fine-mesh wire cloth. The water splashed round by the roll comes in contact with the screens and a good deal passes through. To stop the washing action with this apparatus it is necessary to have a wooden slide to slip in, in front of the wire, so that the water splashes against the wood and falls into the trough again.

The washing of the rags is effected in the following way. The breaker is filled with water and the rags are thrown in, circulation being at first assisted by means of a 'stick' or wooden paddle. When the required amount of rags has been furnished, the drum washers are let down until the lower portion of the drum is immersed to a depth of about 6 or 8 inches. The drums are driven by means of a belt which is connected to the shaft of the breaker roll. As soon as the drum is down, it starts to pick up dirty water and discharge it into the trough, and so to the drain. In order to compensate for the water being removed, fresh water is run in from the tap, and the washing proceeds until the water leaving the trough is as clean as that coming in. When this stage is reached the rags are clean and ready to be bleached.

The 'cover washing' is carried on in much the same way. As the rags and dirty water are splashed round by the roll against the wire screens, a continuous flow of dirty water and small fibres passes through the screens and away to the drains. This method is more drastic than the former, and a great deal of fibre is lost through the screens.

During the period of washing the rags are being 'broken in' by the action of the breaker roll on the bed-plate. The principle of the operation is to undo the work of the textile manufacturer and brush out the rags into threads again. The breaking goes on until all the material is 'out of the rag', and into untwisted and brushed-out threads and fibres.

As the rags are cut and broken up, dirt and impurities contained in seams and in the cloth itself are loosened and pass away in the water. At the same time, any buttons and pieces of metal are cut or pulled off by the roll bars, and sink to the bottom of the trough to be caught in the button catchers. Great skill is required in the breaking-in of rags, as they must not be cut up too much or valuable fibres will be detached and will pass away in the washing water. The ideal state is for the rags to be treated to such an extent that they are all out of the rag, but that as many of the fibres as possible are still in a semi-twisted state of yarn.

Irreparable damage may be done to the rags in the breaker if the breaker man is careless in his handling of the roll. It is necessary for him to grip the rags firmly at the commencement in order to tear them up, but as soon as

this has been done the roll should be eased off and the stuff brushed out carefully.

Important fibrillation takes place in the breaker, and when strong rags are being treated, care and skill in the breaking of them will make the beaterman's work much easier and quicker at a later stage. The washing and breaking of rags should on no account be hurried, as this only means bad washing and often needless cutting up of the fibres, and consequent loss of small fibres, besides preventing the proper defibring of the stuff in the beater, and making the stuff work free on the machine.

Rags can never receive too much washing; the more they are washed with clean pure water, the better.

Rag Bleaching

After the rags have been thoroughly washed and broken in, they are ready to be bleached, and this operation either takes place in the breaker itself, or the rags may be emptied into potching engines on the floor below and bleached with a bleaching solution.

Wherever it is carried out, the bleaching consists of adding to the rag stuff a bleaching solution of known strength, which is prepared as described in the chapter on bleaching. The dry weight of rags in the potcher is known, and a sufficient quantity of bleaching liquor is added, in pails, to give the required percentage of dry bleaching powder. Supposing the strength of the solution is 6° Twaddell, then each gallon of liquor will represent ½ lb. of dry bleaching powder, so that if the breaker holds 100 lb. of rags, and it requires 3 per cent of bleach to bring them to the required colour, it will be necessary to add 6 gallons of the liquor.

No hard-and-fast rule should be made as to the number of gallons to be put into each grade of rags, but rather a standard for colour should be adhered to, in order to give regularity to the stock. It happens often that one boil of rags will only require 2 per cent of bleach, while the next may require as much as 4 per cent to give the same colour. Such wide variations as this should not, of course, occur if the sorting and boiling have been properly carried out, but with some 'prints' great trouble is experienced in getting rid of certain colours, due to the so-called fadeless dyes in use for printing shirtings and such-like textiles.

It is the practice in some mills to run the bleached stock into steeps or drainers and there to allow the bleach to exhaust itself. This method has the advantage that it allows the bleaching in the potcher to be more rapidly carried out, and it also enables the whole of the bleaching action of the liquor to be

exhausted, so that there is no waste. It entails, however, the provision of very large draining tanks or chests, made of concrete and fitted with perforated false bottoms. The liquor may be retained in contact with the stock for any length of time, and then, by the opening of a valve the liquor is drained off into a sump, and the rags are dug out and sent to the beater room.

One great disadvantage of this procedure is the fact that it exposes the bleached rags to dust and dirt, which are always floating about, and it also means that a great deal of labour has to be expended in digging them out and conveying them to the beater room. To get over the difficulty of handling the rags, they may be run, with the spent liquor, into hydraulic presses and pressed into cakes ready to be taken up to the beaters or into a concentrator. In this way they are more easily stored and kept free from dust.

The third method is to break and bleach the rags in a breaker situated immediately above the beater. When the bleaching has been completed the rags may be washed free of bleach liquor by putting down the drum washer and running in fresh water for a quarter of an hour or so. When the beater is empty the bleached stuff is run down straight into it, and so no time is lost, no dirt comes in contact with the stuff, and no storage-room for half stuff is required. This is satisfactory for good white rags, but to get the best colour in *low-grade rags* the drainer method is by far the best.

The former method has the drawback that it is often necessary with a mixed furnish of various grades of rags to break and bleach them together. It will be obvious that this course is not always satisfactory, as such rags as linen, canvas and cotton seconds do not require the same treatment in the breaker, or the same amount of bleach. This trouble is usually overcome by breaking, bleaching and beating the various components of the furnish separately, and then mixing them in the machine chests. This is the most satisfactory method from every point of view, but it requires sufficient beaters, and, above all, very large machine-chest capacity to take the contents of a complete battery of beaters at one time. It is also necessary that the breakers should be of much greater capacity than the beaters, as the density of stock in each operation is very different.

Unless the bleached rags are carefully washed before being emptied to the beaters, a small amount of 'anti-chlor' must be added to the beater when furnishing, when it is otherwise permissible, in order to free the stuff from the last traces of chlorine. If this precaution is not taken and much has been left in the rags, endless trouble will be experienced from froth and variations in the shade of paper.

The anti-chlors in general use are sodium sulphite and sodium hyposulphite, and they depend for their efficiency on the percentage of sulphurous acid, as

SO_2, which they contain. The hyposulphite is more economical in use, but is supposed to have an injurious effect upon the machine wires, owing to the formation of free acid. This, however, does not seem to be really true in practice, as we have run a wire for 18 weeks on a machine making 15 tons of rag writing papers per week, and every beater was freed of excess bleach by hyposulphite of soda.

Loss on Overhauling and Dusting

The following statistics were carefully made in the rag loft during 4 weeks, in order to find the loss on each separate grade of rags from the time they entered the mill until they were ready for the boiler.

Normally, the dust from both dusters was not weighed for each lot, as this would entail a great deal of delay, but for the purposes of this trial the dust was carefully weighed for each grade.

	Cwt.	*Qr.*	*Lb.*	*Cwt.*	*Qr.*	*Lb.*
1. Second white cottons (dirty) (low-quality outshots):						
Gross weight of bales				63	1	2
Less tare (bagging, hoops) .. .. Loss 4.34 per cent	2	3	1			
Less 'mulch' and rubbish, buttons and unusable material .. .. Loss 3.01 per cent	1	3	8			
Loss due to dust in first duster before sorting rags, 1.32 per cent; Loss due to cutting by machine—*i.e.* second duster—2.7 per cent	2	1	11			
Total loss in passing through rag loft, 11.37 per cent				6	3	20
Nett weight of paper-making material				56	1	10

This would be considered a very good consignment.
The mulch is very low.

	Cwt.	*Qr.*	*Lb.*	*Cwt.*	*Qr.*	*Lb.*
2. A good-looking parcel of old light prints (soft, coloured, clean cottons):						
Gross weight of bales				48	3	13
Less tare (Hessian and hoops) .. .. Loss 3.1 per cent	1	2	4			
Mulch picked out .. .. Loss 4.6 per cent	2	0	15			
Dust from both dusters .. .. Loss 3.91 per cent	1	3	1			
Total loss 11.51 per cent				5	1	20
Nett weight of paper-making material				43	1	21

A good parcel.

3. A parcel of old light prints (mixed soft-coloured cottons):

	Cwt.	Qr.	Lb.	Cwt.	Qr.	Lb.
Gross weight of bales				122	3	9
Less tare Loss 4.06 per cent	5	0	0			
Less mulch Loss 7.77 per cent	9	0	18			
Less dust from both dusters Loss 4.4 per cent	4	3	3			
Total loss 16.23 per cent				18	3	21
Nett weight of paper-making material				103	3	16

A fair lot.

4. English country seconds (mixed):

	Cwt.	Qr.	Lb.	Cwt.	Qr.	Lb.
Gross weight of bags				86	3	1
Less tare (bags) Loss 2.7 per cent	2	1	4			
Less mulch picked out Loss 5.1 per cent	4	1	24			
Less dust Loss 4.04 per cent	3	2	1			
Less 'thirds' and low-quality cotton material Loss 9.23 per cent	8	0	21			
Total loss 21.07 per cent				18	1	22
Nett weight of paper-making material				68	1	7

A very poor lot.

5. English country seconds (mixed):

	Cwt.	Qr.	Lb.	Cwt.	Qr.	Lb.
Gross weight of bags				118	0	0
Less tare (bags) Loss 2.02 per cent	2	1	26			
Less mulch picked out Loss 11.7 per cent	13	3	7			
Less dust Loss 4.02 per cent	4	3	0			
Less 'thirds' Loss 11.3 per cent	13	1	13			
Total loss 29 per cent				34	1	18
Nett weight of paper-making material				83	2	10

A very bad lot.

In addition to the various materials already sorted out as waste, there is a further variety, usually called 'thirds', which consists of low-quality rags, dark colours, very dirty pieces, etc., which, although not suitable to be included in the grade being sorted, are nevertheless paper-making material.

There are various ways of dealing with this. Some mills sell it back to the rag merchants, while others use it in lower grades of paper, colours, etc., and again, others boil it drastically and bleach it in gas chambers, and are thus able to use it in ledgers and other coloured papers.

A certain amount of these rags was sorted out of some of the grades already referred to during the trial, and the quantities are appended:

	Cwt.	*Qr.*	*Lb.*
No. 1	—	—	—
No. 2	3	0	15
No. 3	5	1	10
No. 4	8	0	21
No. 5	13	1	13

It will at once be seen that the amount of low-quality rags rises with the mulch and rubbish.

The market value of the above rags is not more than 70 per cent of the value of the original parcels from which they were extracted, and is often much less. Besides the low-quality rags, another grade is sometimes sorted out, consisting of strong pieces, such as light cords, canvas, ticking, brown linen linings, etc. These rags are usually kept separate, and given more drastic treatment and used for ledgers or strong thin papers. They may be boiled and bleached in the same way as canvas, in which case they will not usually come up to a very good colour, or they may be gas bleached. They will always be yellowish in colour and not suitable for bright-looking papers, if their strength is conserved.

It will be seen from the foregoing that the question of deciding on the actual value of a parcel of rags is a somewhat complicated business.

First of all the bulk of the rags has to be valued, then the various grades picked out have to be given separate or lower values, and finally the prices obtainable for the mulch, dust, and packing material, Hessian, etc., must be taken into account.

As a result of many trials it has been proved, to our own satisfaction, that it pays in every case to buy the best grades in the first place. This method reduces to an amazing extent the number of hands required in the rag room, and leads to much greater uniformity in the half stuff.

The following figures of 'dust' were obtained in four separate weeks. The dust from each duster was weighed separately. It may be noted that the heavy dust, grit, etc., from the first duster has no value, while the fluffy dust from the second duster may be sold as manure or for other purposes, for a pound or two per ton.

WEIGHT OF RAGS DUSTED AND DUST COLLECTED AT FIRST DUSTER

	Rags Dusted Cwt.	Qr.	Lb.	*Dust* Cwt.	Qr.	Lb.
1st week	346	3	17	4	3	23
2nd „	290	3	16	5	0	10
3rd „	439	1	6	3	2	8
4th „	339	3	3	4	3	26

(The dust is about 1.05 per cent and is not very consistent)

Second Duster, after Rag Cutter

1st week	340	2	0	9	1	8
2nd „	333	1	20	9	1	0
3rd „	342	3	13	8	3	10
4th „	339	0	17	9	3	15

(The dust is about 2.7 per cent and is fairly constant)

CHAPTER IV

BOILERS—BLEACHING—PREPARATION OF BLEACHING SOLUTION—GAS BLEACHING

BOILERS

THERE are three varieties of boilers in common use in the paper mill, Rotary Boilers, Spherical and Cylindrical, and Stationary Boilers of many shapes and sizes. The spherical rotary boiler is the most efficient, especially for dealing with all classes of rags. The mixture of rags and liquor is most thorough and continuous. There is less heat lost by radiation than in other types of rotary boilers. They are very easily filled and emptied. The drastic churning action which prevents clumps or balls of stringy rags being formed causes a certain loss of fibre.

Owing to the difficulty of housing very large spherical boilers some mills use those of cylindrical shape.

Owing to their shape and the great weight they have to carry, they have to be built of thicker plates than the spherical boiler. Sometimes the larger sizes are supported by revolving rollers on standards. Steel bands are fitted, which make contact with the rollers. These help to take the weight off the end plates and the trunnions. As the rags do not gravitate to the centre, but roll continuously in one circle, there is more trouble with clumps of rags.

More labour and time are required in filling and emptying, it being necessary for a man to enter the boiler and spread the rags to the ends from under the manholes, and drag them back when emptying. In both types steam and water are admitted through the trunnions. They are also fitted with pressure gauges and safety valves, and are revolved by worm and pinion gearing. The blow-off cocks are on the side opposite the manholes, and are shielded inside by perforated metal plates to prevent loss of rags and fibre.

When used for scalding and disintegrating waste paper and broke, the speed should be increased to increase the internal friction. One revolution in three minutes is sufficient for rag boiling, but for broke scalding the speed should be three to five revolutions per minute, which is about all that a heavy boiler will safely stand.

Stationary Boilers for Rags.—The usual stationary rag boiler is dome-shaped.

The rags rest on a perforated plate at the bottom, and steam is admitted into the space between the plate and the bottom.

The steam blowing upwards agitates the rags and forces the liquor through the mass. The agitation is, however, very imperfect and the rags frequently pack into dense masses, which then get little contact with the boiling liquor.

This type of boiler is very economical for use with good rags which do not require very severe boiling. There is no loss of fibre through friction, and little expense for upkeep as compared with rotaries, which require power to drive, oil, packing for glands, and repairs to running parts. The blow-off steam may be used to heat water for rag washing, etc. It is safer to use, as there is no mechanical strain apart from the boiling pressure. The rags may be filled through an opening at the top, but they have to be dug out by hand.

There are still some mills, making hand-made papers, which boil their rags in open tanks with wooden lids, but only rags requiring slight treatment can be dealt with in this way.

For esparto, straw, etc., vomiting stationary boilers are used. These are made much larger than rag boilers, a common size holding 5 or more tons of esparto. When larger sizes are used, more elaborate and expensive devices are necessary for washing. The stock rests on a perforated false bottom through which the liquor drains and collects over the steam inlet pipe. The latter is extended either outside or inside the boiler, so that the liquor and steam are forced upwards to the top of the boiler and spread over the charge by a spreader plate. A constant circulation of liquor is maintained by means of this arrangement.

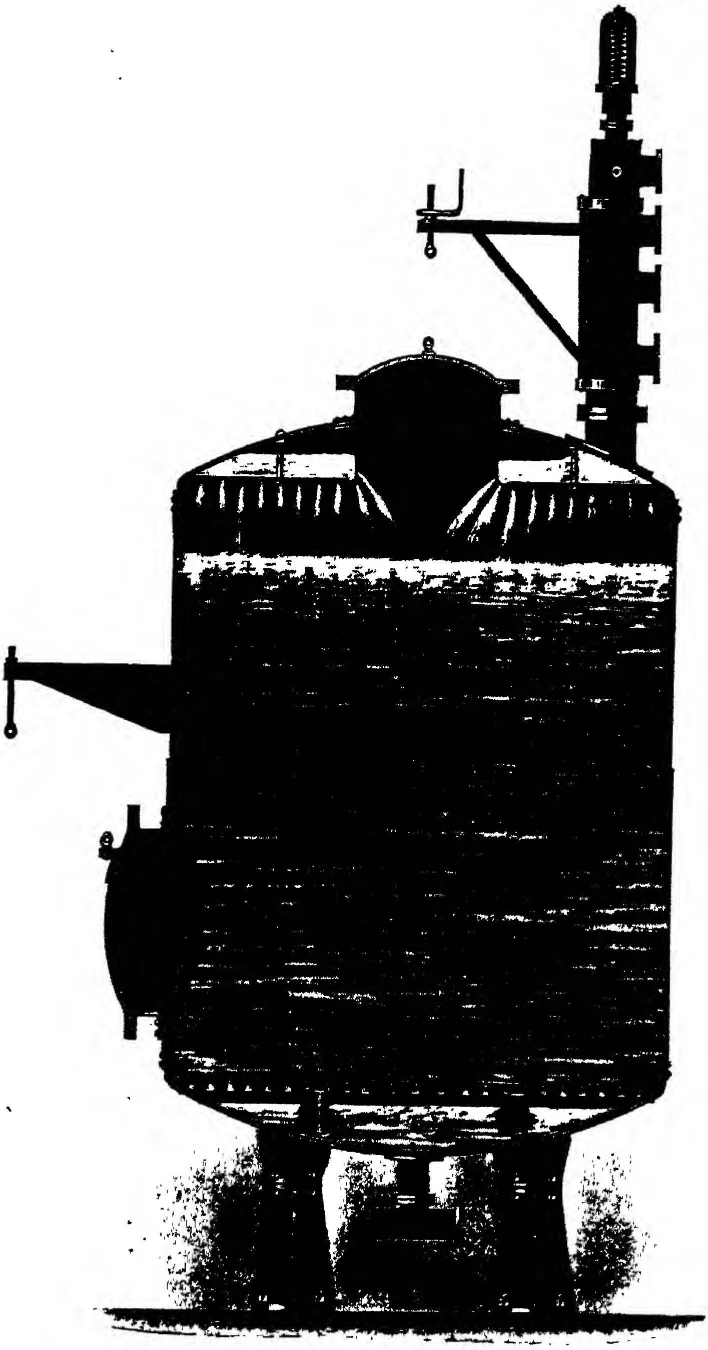
The boiler has the usual pressure gauge and steam fittings, and also a run-off pipe to convey the spent liquor to the soda recovery plant.

It is usual nowadays to cut out esparto or straw from a Sinclair boiler by means of a jet of water at high pressure.

Bleaching

In preparing half stuff for white printings and high-grade writing papers, the colour obtained by boiling and washing the stock, whether it is wood, esparto or rags, is dull or brown, and must be further whitened and made pure. This is effected by the process known as 'bleaching'.

The laundry and washerwoman bleach collars and other white garments after washing. Bleaching has been in vogue for many years and the earliest method is that known as sun bleaching; this consists in damping the material to be bleached and placing it out in the sun, where 'oxidation', which is the



[Messrs. Bertrams Ltd.

FIG. 8.—SINCLAIR STATIONARY VOMITING BOILER FOR ESPARTO GRASS

The liquor is shown percolating through the perforated baffle plate at the top, after ascending the vomit pipe

chemical reaction which causes bleaching to take place, occurs. This method is very slow and uncertain.

Chloride of lime or 'bleaching powder' is still employed in many mills as a bleaching agent. It is prepared by passing chlorine gas over slaked lime. The lime absorbs a large quantity of the gas and holds it so long as it is kept dry and in air-tight packages, which consist usually of large wooden barrels. The compound thus formed is called 'bleaching powder' and its formula is taken to be $CaOCl.Cl$.

Ca—Calcium.
O—Oxygen.
Cl—Chlorine.

The powder contains about 35 per cent of available chlorine.

When this powder is mixed with water, two compounds are formed—namely, calcium chloride, $CaCl_2$, and calcium hypochlorite, $Ca(OCl_2)$. This salt, $Ca(OCl)_2$, is the actual bleaching agent, and forms oxygen by splitting up thus:

$$Ca(OCl)_2 = CaCl_2 + 2O.$$

When the oxygen splits off from the calcium chloride it is in the nascent state, and it is then that it oxidises the colouring matter in the rags, esparto or wood fibres.

Preparation of the Solution

The best way to prepare the solution for use in the mill is to have large deep cast-iron tanks fitted with effective agitators. They should be tall and narrow, and enclosed, except for an opening at the top to allow for the furnishing of the bleaching powder. The building in which the tops of the mixers are situated should be well ventilated, as the operation of emptying the powder from the barrel into the mixer is very unpleasant.

As the powder usually arrives at the mill in casks containing about 7 cwt., the capacity of the mixer should be not less than 1600 gallons. This will allow plenty of room for sufficient water to be added to make the solution at standard strength 6° Tw. (5 lb. to 10 gallons of water) with one cask of bleaching powder, and allow for the lime sludge, which will occupy some space at the bottom.

An efficient and economical mixing plant is shown in the illustration (Fig. 9). Though this seems a very elaborate arrangement and its working at first sight rather complicated, it will be found that, by careful manipulation, the utmost available chlorine will be extracted from the powder and the sludge left quite innocuous, and there will be the minimum of waste.

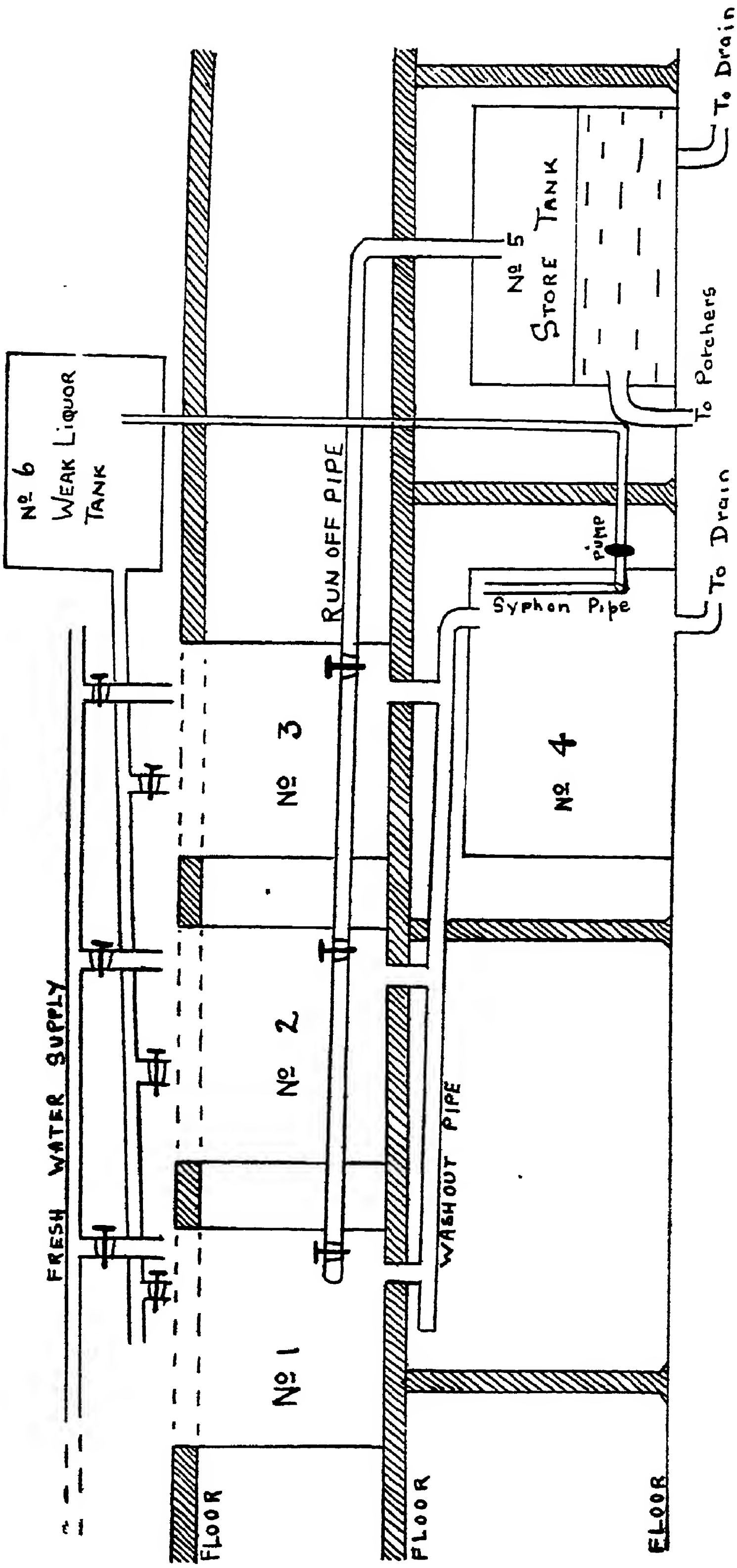


FIG. 9.—ARRANGEMENT OF BLEACH-MIXING PLANT, USING BLEACHING POWDER
There are three mixers, fourth wash tank, etc.

The plant occupies part of three floors, the top floor containing the water pipes and a weak liquor tank. Provision must also be made for lifting tackle for emptying barrels, and driving gear for the agitators (not shown in the illustration). The second floor serves as a support for the mixing tanks, though an arrangement of girders is all that is necessary. Below the mixers is a tank (No. 4), which is used as a final settling tank for the last mixing of lime sludge. The store tank is covered in, and should be of ample size.

The method is to charge a mixer with water and bleaching powder. The agitator is started and run for 20 to 30 minutes; it is then stopped and the lime allowed to settle. This takes from 2 to 3 hours, often a good deal longer, but plenty of time must be allowed for the lime to settle below the level of the draw-off valves, which are about 12 inches above the bottom. If the solution is drawn off before the lime has settled properly, the lime will foul the pipes and store tank and get into the bleaching potcher, which is very undesirable.

If the size of the mixing tanks (Nos. 1, 2 and 3) is taken at 9 feet deep by 6 feet diameter, each will hold about 1500 gallons of solution, allowing 12 inches at the bottom for the sludge; the mixer is not filled to the brim on account of the agitators splashing the liquid over the edge.

Two barrels, approximately 7 cwt. each, are emptied into No. 1 with fresh water. This ought to give a solution of 10° to 12° Tw., which is too strong for general use. To reduce it to 6° Tw. (working strength), No. 2 mixer is filled with water, and the two are run together to the store tank. If the solution is under 12° Tw., of course a little less water must be run from No. 2. A Tw. hydrometer is constantly used to check this strength, and a measuring stick marked off in 100-gallon sections is necessary for the amount of liquor or water in the mixers.

No. 1 mixer will now contain sludge, which must be again stirred up with fresh water. If the mixer is half filled, the solution should stand about working strength (6° Tw.). If it is stronger, a little more water will correct the density as it is let down to the store tank. If weaker, the strength may be brought up from the charge in No. 2. No. 1 mixer may now be filled with water and stirred for the third time, and the whole contents run into No. 4 tank, with a light flush of water to wash out all the sludge.

This last lot, after settling, will give a weak solution, which may be pumped to the weak liquor tank, from whence it can be drawn to furnish the mixers instead of, or in addition to, fresh water. In the meantime, No. 2 mixer is charged and worked in the same way, and then No. 3.

The mixers will thus be used in turn for making a strong solution, a working solution and a weak solution for diluting purposes, and, by having three

mixers, plenty of time is allowed for the settling of each charge. In fact, four or more solutions can be made from each charge, the arrangements allowing for endless variations of the procedure, besides keeping a constant and correct solution in the store tank.

The three mixers, being regularly emptied to No. 4 tank along with the sludge, are very easily kept clean. The store tank requires to be cleaned frequently, as a residue of lime will be found at the bottom, which becomes very hard and difficult to remove. No. 4 tank is fitted with a manhole or door close to the ground level, to facilitate the removal of the sludge.

Where only a small supply of bleach has to be prepared, one or two mixers will be sufficient, as the sludge can be stirred several times and smaller charges of powder used.

Careful supervision has to be exercised over this process to see that the stock solution is kept at regular strength, and that it is not run off to the store tank until it is quite clear.

Liquid Chlorine may be obtained in steel cylinders holding about a ton, or in tank wagons ready for use. It may be used either as a bleaching agent or as an auxiliary to bleaching powder. As we have already seen, bleaching powder contains only about 35 per cent of chlorine, the remaining 65 per cent is simply the 'carrier' and of no use. It has, in fact, to be washed away as useless sludge or lime mud, and it is difficult to get rid of in any case. About 75 per cent of this residue is lime, which can be combined again with chlorine to form the same soluble bleaching agent as that which was extracted originally from the bleaching powder.

By connecting a cylinder of liquid chlorine to the bleach mixer and allowing the chlorine to run in while the agitation is going on, a very strong bleaching solution is formed. The settling is much more rapid, and the chlorine will have acted on the lime and combined with it, forming 'hypochlorite', so that the amount of the lime left as sludge, in the form of calcium carbonate, is very small indeed, only about 25 per cent of the normal amount left, when liquid chlorine is not used.

This means that the mixers need not be washed out so often, and also it reduces the number of mixings or agitations always required in the first method to extract the whole of the chlorine. This process, as will be easily seen, is simply the rechlorination of the free or 'carrier' lime present in the bleaching powder.

Most mills have now abandoned the use of bleaching powder entirely, and are making all their bleach liquor from lime and liquid chlorine.

Various special forms of plant have been devised in which this process can be carried on, but as a general rule paper-makers have preferred to adapt

their existing bleach plant to the needs of the new process. This has been done very successfully, and, in fact, when the bleach mixer is a plain cylindrical tank, standing on end and fitted with a simple gate or horizontal type of agitator, it makes what is possibly the best type of chlorination vessel for practical purposes. It is desirable that the tank should be fairly deep (say at least 12 feet) and that it should have no baffles or other devices which may cause rapid vertical currents.

The lime in the process should be a high-grade quicklime which slakes easily. It is necessary that the temperature of the batch of milk of lime, before chlorination commences, should not be more than about 65° to 70° F., and thus a lime which will slake with cold or warm instead of hot water is an advantage. The charge of lime should be slaked in as small a quantity of water as possible. The thick milk so produced is pumped to the chlorination tank and can then be cooled, as well as diluted, by filling up the chlorination tank with cold water. During the chlorination the temperature should not be allowed to exceed 90° F.

Chlorine is admitted to the chlorination vessel, in the liquid state, through pipes reaching almost to the bottom of the vessel. A distributing device, such as a coil perforated at regular intervals and lying close to the floor of the tank, is a decided advantage.

The progress of the reaction between the lime and chlorine is checked as follows:

> Remove a sample of the muddy liquor and allow it to settle in a hydrometer jar.
>
> Test with a Twaddell hydrometer graduated in fifths or tenths of a degree.
>
> When the test shows that the batch is nearing completion, samples should be taken at close intervals and from these tests the actual end point can easily be predicted.

This method of testing is quite accurate enough for works control purposes, but the Twaddell to which the batch can safely be taken must be determined in the first place by more exact (analytical) methods. A typical batch at one mill was as follows (initial temperature 67° F.):

	Temperature	*Twaddell*
After ½ hour	70° F.	2.0° Tw.*
„ 1 „	78° F.	5.5° „
„ 1½ hours	83° F.	9.4° „
„ 1 hour 40 min.	84° F.	10.4° „

* These Twaddells refer to warm liquor five minutes after sampling. They will, of course, be higher if the liquor cools.

At this stage the batch was given five more minutes, and the control valve was then closed. A sample was taken and twaddled. It was then 85° F. and 10.8° Tw. and the batch was finished.

When a batch is completed, it is allowed to settle, and is run off and the sludge washed in the normal way. The quantity of sludge is small, and consists chiefly of impurities present in the original lime, with a little reserve lime to maintain alkalinity in the solution.

In some mills where it is not possible to use liquid chlorine from tank wagons, 17-cwt. cylinders may be used in an exactly similar manner. The process control in these cases can be achieved, if desired, by weighing the cylinder.

Gas Bleaching.—In this older method of bleaching by chlorine gas, the chemical reaction is again one of oxidation. The chlorine gas passes through damp half stuff, and the chlorine takes up hydrogen from the water or moisture present, forming hydrochloric acid and setting free oxygen. This oxygen is very active indeed, and will both remove colouring matter and reduce shive or lignin, on which the ordinary bleach has had little or no effect.

Great care has to be taken that the action is not too drastic and that the stuff does not heat, or serious damage will be done to the cellulose.

For bleaching low-coloured rags and for destroying the shive in linen, a gas bleaching chamber is very useful. A chamber holding 1 ton of rags is a very good size, about 6 feet square by 8 feet in height, and having cross-bars of wood on which the pulp is laid in order to allow the gas to penetrate all through the mass. This chamber is closed and the door made air-tight by a packing of wet paper. The retort should be on the outside and open to the air, to obviate the risk of the attendant being gassed while putting in the charge. The retort is of heavy cast iron and heavily lead lined. The top is also of lead and is designed to fit on the base with a water channel, similar to a gas tank. A lead pipe from the top communicates with the inside of the gas chamber.

For a ton of low-grade rags the following quantities of chemicals are required: 30 quarts of sulphuric acid, ½ cwt. of salt, ¼ cwt. of manganese dioxide. The salt is placed in the retort with 6 gallons of water. The manganese dioxide is added and the mass stirred into a paste. The top is then put on and the pipe connected.

The sulphuric acid is filled in through a funnel on the top in three separate lots. Some steam is turned on and the chlorine gas and steam pass into the bleaching chamber and mix with the rags.

The process occupies about 12 hours and is very drastic. The quantities are varied according to the stock being bleached.

Bleaching Methods.—There are two methods of bleaching, a rapid and a

slow. In the first, the bleach is run into the potcher after the stuff has been broken in and washed. More bleach is required in this method to whiten the stuff, and its strength suffers accordingly. In fact, an excess of bleach is run in, and this excess has to be washed out and finally killed with anti-chlor. With this method the colour of the pulp is said to 'go back' a little. The second method is more economical. Sufficient and no more bleach is used than is calculated to bring up the colour of the stock. The stuff is well mixed with the bleach in the potcher and then run into tanks or steeps, where the chemical action proceeds to its conclusion more slowly and naturally. This gives a better colour and does not do so much damage to the fibres. Some threads in rag stock that cannot be made to give up their colour with a rapid bleach will be found to have become quite colourless in 24 hours. This system, of course, requires a great deal of space for draining tanks, and entails more handling of stock. Steam heating during bleaching is often resorted to, as with esparto and wood pulp. While this is of great assistance in obtaining a good white colour quickly, it requires to be used with caution; 90° F. is the highest temperature that should be allowed. Above that the cellulose will be attacked by the bleach (oxidised) and lose strength to a very great extent. The fibres will also return to a bad colour after cooling down.

Esparto fibres, in particular, are very apt to be destroyed by too high a temperature, and will cause trouble by being slimy and soft and sticking to the press rolls of the machine. A very little dilute acid is not to be despised as an aid to obtaining a good colour, but great care must be taken when using this. It should be added to the potcher very much diluted and in small quantities, otherwise chlorine gas will be evolved and escape into the atmosphere, causing great discomfort to the workers besides loss of chlorine.

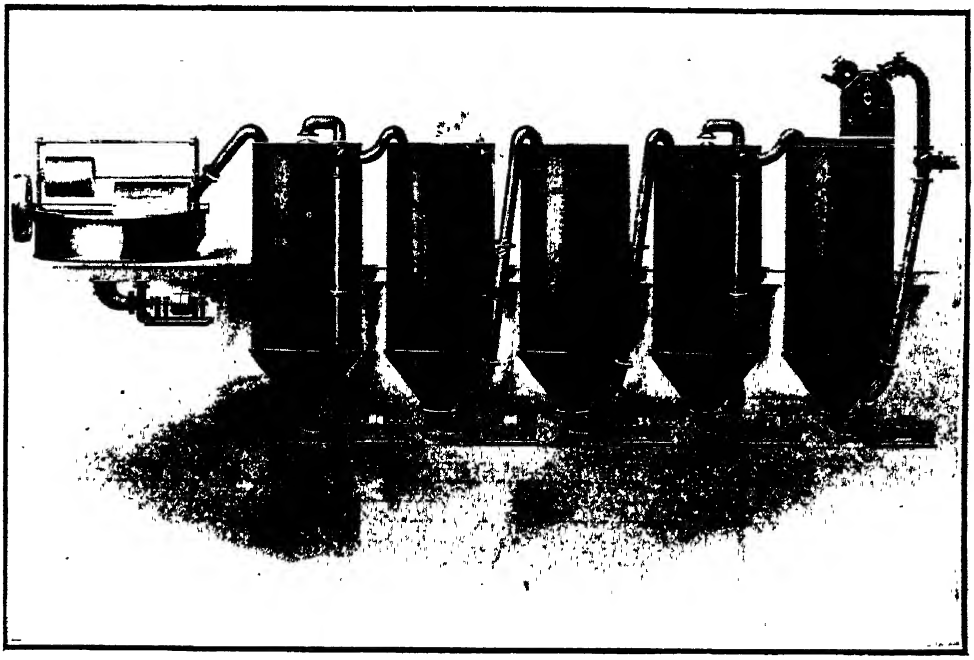
A very good accelerator of this type is about ¼ pint of alum solution (20° Tw.) in about 2 pints of water for 200 lb. stuff. Acetic or sulphuric acids are sometimes used where the colour is difficult to bring up to a good white, but none of these should be used except in unusual circumstances, and then only with great care.

The cold bleaching of esparto and wood pulp is now generally carried out in a series of bleaching towers. This system was introduced by Messrs. Masson, Scott and Co., and has been almost universally adopted in esparto mills. It takes up very little space and is economical and less costly than the plants necessary for hot bleaching.

The towers are large vertical structures made of cast-iron or concrete, lined with glazed tiles or glass, the usual size being about 8 feet in diameter by 16 or 20 feet high. The bottom is sharply tapered, so that it is not possible for the pulp to lodge anywhere. At the bottom of the taper is a bend, 2 feet

in diameter, giving access to the circulating pump, which is a very efficient apparatus, and can deal with the whole of the contents of the tower in a quarter of an hour. There is a valve provided to shut off the contents of the tower should the pump have to be dismantled, and also a wash-out valve for cleaning purposes.

The illustration (Fig. 10) clearly shows the lay-out of the complete system. The pulp or grass is broken up and washed in the breaker, and is then concentrated by removing water with the drum washers, emptied and pumped into the first tower, to which the strong bleach is added, or the first tower



[*Messrs. Masson, Scott and Co. Ltd.*

FIG. 10.—BATTERY OF MASSON-SCOTT BLEACHING TOWERS WITH POTCHER AND CONCENTRATOR

may simply be used as a collecting tank for raw pulp, which is passed on and bleached in the second tower. When the bleach is added, the pulp may be circulated on to the next tower, and so on, until it reaches the last tower, or if necessary it may be circulated round several times in the first tower by the arrangement of pipes and a two-way cock. When the pulp is discharged from the pipe into the top of the tower, it strikes a conical spreader plate, which mixes it thoroughly and helps to exhaust the bleach. By the time the pulp reaches the last tower it should be thoroughly bleached, and a sample may be taken to examine the colour. If it is not sufficiently bleached, a further lot of bleach liquor may be added, and the contents circulated round the last tower several times until the bleaching is completed.

The battery shown in the illustration consists of a breaker fitted with two ordinary drum washers, and is capable of dealing with the stock for 60 tons of paper per week. The stuff is pumped from the breaker to the first tower, which is fitted with two discharge pipes, one into the second tower, and one back into the first tower. The first or fourth towers have this arrangement of pipes and also spreader hoods for thoroughly mixing the pulp. The last tower is fitted with a concentrator, by means of which the last traces of bleach liquor are removed, after washing in the last tower, and the thickened pulp is run or pumped direct to the *presse-pâte* chest.

All the pumps attached to the towers may be driven from the same shaft.

This arrangement of bleaching towers, worked in conjunction with a battery of Taylor or Tower beaters, forms an excellent equipment for dealing with esparto and wood-pulp stock.

The pulp is mechanically handled throughout, and is enclosed and away from dirt and dust the whole time.

The first tower is used for adding the bleach and mixing, and the last tower for washing. The capacity of the plant depends on the number of towers installed, but with each tower holding 2 tons dry weight, and delivering this quantity every 4 hours it will be seen that the capacity of a five-tower plant will be approximately 60 tons per week of finished paper.

Bleaching Wood Pulp.—For bleaching wood pulp, an ordinary Hollander type potcher of large capacity is generally used. This may be made of cast iron or concrete lined with glazed tiles to assist circulation, and is fitted with a large cast-iron roll with projecting bars.

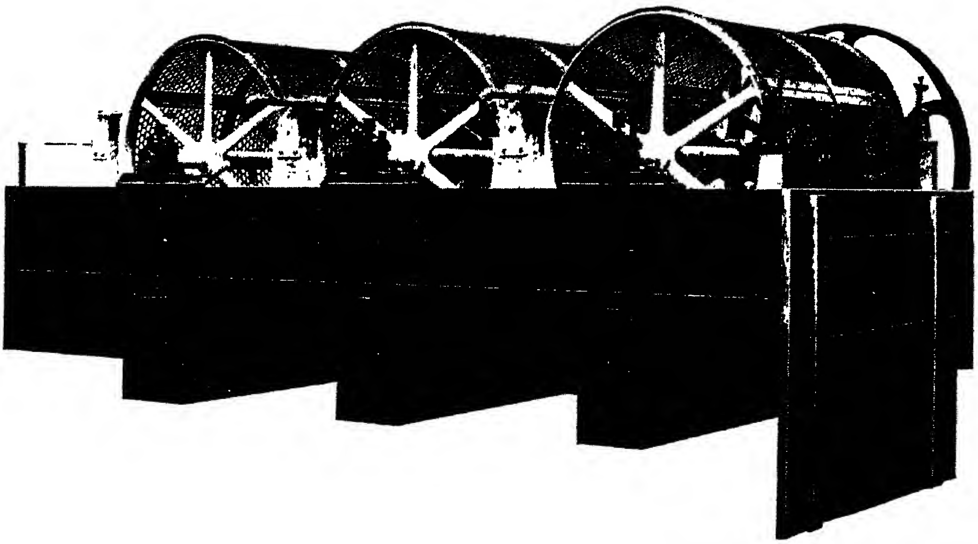
Steam is always used to heat the stock after the bleach has been added, but the temperature should not be allowed to exceed about 80° F., or damage will be done to the fibres and the colour of the half stuff will deteriorate if it is allowed to lie in drainers.

The action of the bleach is very rapid at first, so that a quick and thorough mixing and circulation of the stock is necessary. When heat is used, the bleaching is accomplished in about 3 or 4 hours, but if drains are provided the stuff may be emptied after about the first hour or so, and the bleaching completed while the pulp is at rest. When, however, the bleached stuff is to be run straight into the beaters, at least 3 hours has to be allowed, with from 6 to 10 per cent of bleaching powder, calculated on the dry weight of pulp. The amount required, of course, depends on how easily the pulp bleaches, the colour required and the time available.

In this latter method, when the pulp is run straight to the beaters, the bleach residues must be removed by the use of a drum washer and fresh water, and it will usually be necessary to add a little anti-chlor until no trace of bleach is

left. Unless this is done, endless trouble will be experienced in keeping the colour of the paper from varying in shade.

In the former method, where the pulp is allowed to lie in the drainer, it should not be left for very long, otherwise it will begin to go back in colour, and that part of it which is exposed to the atmosphere will turn yellow. The bottom portion nearest the floor of the drainer will also discolour badly, and will retain a good deal of water and bleach residues, unless the perforations in the false bottom of the drainer are kept clean.



[*Messrs. James Bertram and Sons Ltd.*

FIG. 11.—THREE-DRUM WASHING AND CONCENTRATING MACHINE, FOR WOOD-PULP, RAGS OR ESPARTO GRASS

Bleaching should always be carried out with the stock at as thick a consistency as possible. The density, of course, will depend on the type of machine in which the bleaching is carried out, but even if it is in an ordinary Hollander, the stock should be as thick as possible.

A cheap, speedy, and continuous method of drying bleached pulps to about 70 per cent moisture or less is sorely needed by many mills to-day. It is true that there are several Rotary Vacuum Filters on the market, but these are troublesome and inefficient in many ways. Some of them work quite well on wood. On rag stuff and esparto there is the *presse-pâte* which does well in some mills and is continuous. There are hydraulic presses and hydro-extractors, but these are both slow and intermittent. The continuous screw press has not, unfortunately, been brought to a sufficient satisfactory state of perfection to be suitable for all types of fibres. The multiple drum concentrator (Fig. 11) is used in many mills, and this is satisfactory where the stuff can be taken straight to the beater.

REDUCTION TO HALF STUFF—WOOD PULP—ESPARTO GRASS—STRAW

WOOD pulp is the most important raw material at present known to the paper-maker. At the present time, the paper-maker in Great Britain need not necessarily concern himself with the methods employed in the isolation of the cellulose from wood, for, unlike esparto, it comes, except in one or two cases, into the country already prepared for making into paper. Wood pulp is divided into two distinct classes: first, 'mechanical' wood, which is simply ground soft wood, and is in no sense a pure cellulose; and second, 'chemical' wood, which is wood cellulose chemically isolated from wood.

It must be recognized that wood pulps cannot be rigidly classified and graded. The physical properties are usually of chief importance, and the fibrous nature of the material does not lend itself to precision testing in terms of rigid specifications. However, the days of offering pulps merely by samples are passing. Testing at the pulp mills is usually thorough, and careful control is always rewarded by better results in the market. Testing by the paper mills, board mills, and speciality consumers has now reached a high plane in many laboratories. The test of practical use in the paper mill tells the second, and decisive, half of the story.

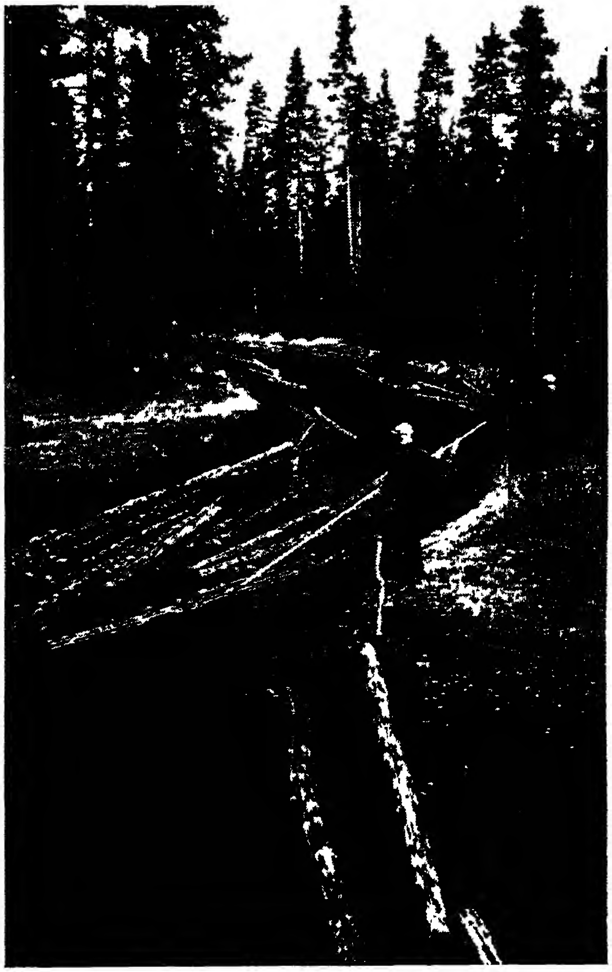
The basic factor is the pulp wood, its species, rate of growth, condition, and preparation.

The wood-pulp business was built up largely on spruce. The fibre length (about 3 mm.) is just right for most paper and board products. Spruce is low in resin content and therefore adapted to mechanical, acid, and alkaline processes. The wood is unusually uniform and the colour is bright. The various species of spruce—'whitewood' (*Picea excelsa*) in Northern Europe; white spruce (*Picea glauca*), black spruce (*Picea mariana*), and red spruce (*Picea rubra*) in North-Eastern America; and Sitka spruce (*Picea sitchensis*) on the west coast—have much the same fibre characteristics, but vary somewhat in density and pulping action.

The closely related species, such as balsam fir (*Abies balsamea*), of lower density, in Eastern Canada and the United States, and white fir (*Abies grandis*) on the Pacific coast, have naturally come into use to supplement the demand

for spruce type of fibre. Closely parallel, especially for chemical pulps, are eastern hemlock (*Tsuga canadensis*) and western hemlock (*Tsuga heterophylla*), very low in pitch, which is the main wood for the new industry on the west coast.

Pine has been taking a larger place by reason of its suitability for the alkaline sulphate process, which dissolves the higher content of resins. 'Redwood'



[*Nokia Aktiebolag*

FIG. 12.—FLOATING LOGS DOWN FROM THE FOREST

(*Pinus sylvestris*) in Northern Europe and jack pine (*Pinus banksiana*) in America are so much like spruce in fibre characteristics that they are now the usual raw material for the best grades of kraft pulp. The southern pines, long leaf (*Pinus palustris*), slash (*Pinus caribaea*), loblolly (*Pinus toeda*), and short leaf (*Pinus echinata*), with coarser fibres and more difference between springwood and summerwood, have become very important for liner board and medium-grade papers.

Hardwoods are fundamentally different because the fibre length is so much less (1 to 1.5 mm.), and the pulp can therefore never take more than a minor place in the pulp and board industry. For many years the main species was aspen, or poplar (*Populus tremuloides*), a soft hardwood, for the manufacture of bleached soda pulp in America. The scope is steadily widening, and various species of birch, beech, maple, chestnut, cottonwood, gum, etc., have been added to the list. Aspen and beech are used in Europe. Eucalyptus and other hardwoods are being developed in countries not endowed with suitable softwoods. The trend seems to be towards sulphite or sulphate cooking, because of their greater convenience and efficiency compared with the caustic soda process. The use of hardwoods will probably extend in the field of fine papers and perhaps considerably for chemical purposes where fibre size is of no importance.

In general it can be said that the limited supply of the spruce type of pulpwood in the different northern countries of the world is being, and should be, reserved mainly for sulphite and mechanical pulps. Other species will play an increasing part in meeting the world's pulp requirements.

On looking over a collection of wood samples it is interesting to note that the brightness, fine texture, and uniformity of the pulpwoods, particularly spruce, fir, aspen, stand out as raw material giving the appearance of being best suited to pulp manufacture.

Wood preparation deserves mention as a reminder of seasoning to reduce pitch troubles and to aid penetration in the cooking of sulphite pulps, knife barking to ensure best cleanliness and brightness for the highest grades of unbleached sulphite, and careful chipping to aid uniform cooking of all chemical pulps.

The chief countries engaged in the manufacture of wood pulp are Scandinavia, Canada and the United States, Finland, Germany, Czecho-Slovakia and Russia—in other words, those countries which have extensive forests and almost unlimited water-power. Water serves as the chief means of transport of the logs after they have been cut down in the forests, besides supplying the power at the mill. The trees are felled and stripped, and rolled, dragged or carried on light railways to the river, where in the winter they are piled on the ice to await the spring thaws. They are then floated down the river to large traps, formed of wooden booms, close to the mill.

Trees immediately required are floated into the mill. Those to be kept in stock are built into huge piles to be used in rotation when the river is frozen or when the felling ceases. During the passage downstream a proportion of the bark is rubbed off, but this is not sufficient. They are cut up into short lengths of about 2 feet, and are then 'barked' in a machine or by hand, when they are ready to be made into either mechanical or chemical wood pulp.

Mechanical Pulp

Those intended for mechanical pulp are passed to the grinders after having all knots drilled out. The wood pulp grinder consists of a revolving stone of about $3\frac{1}{2}$ to $4\frac{1}{2}$ feet diameter and 2 to $2\frac{1}{2}$ feet on face. This is mounted on a heavy shaft and enclosed in a heavy metal case on which are strong metal boxes fitted with hydraulic pressure arrangements to hold the logs and keep

[*Nokia Aktiebolag*

Fig. 13.—Towing a 'Raft' of Logs across a Lake to the Pulp Mill

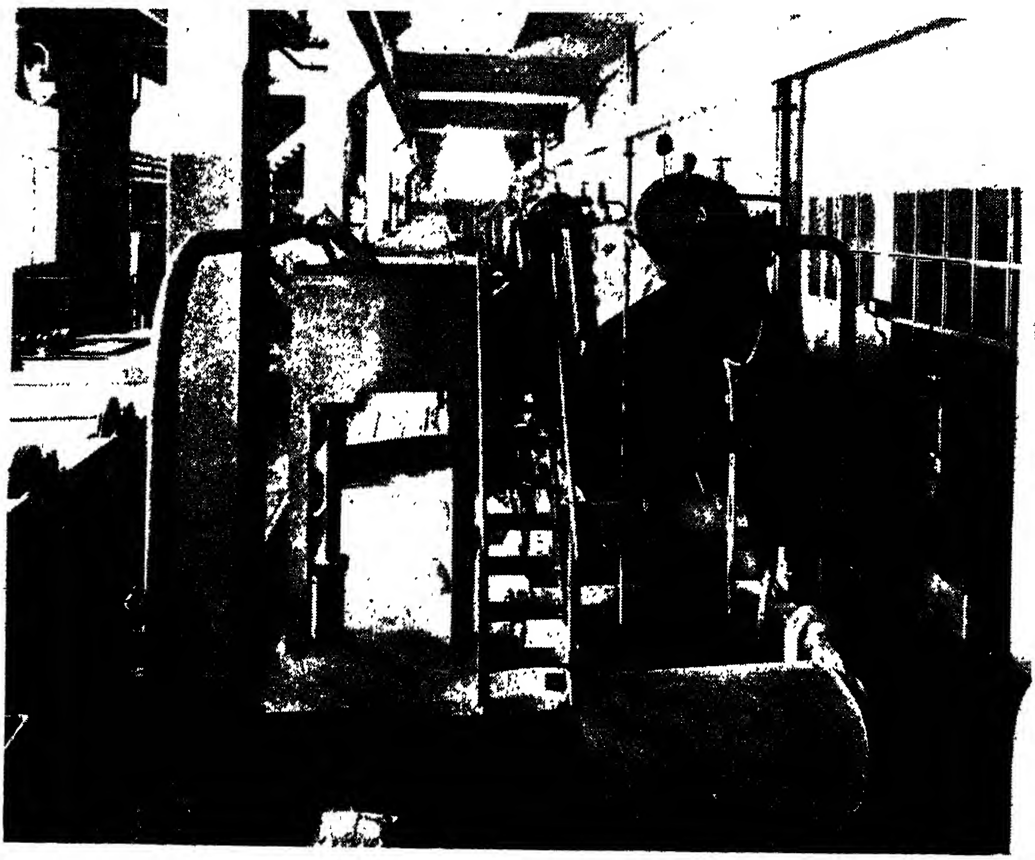
them pressed against the revolving face of the stone. Inside the case, behind each box, is a water spray which washes off the particles of wood as they are torn from the log.

The stone is kept rough on the tearing surface by frequent dressing with special tools; the quality of the pulp and the output depend very much on the condition of the stone. If the stone is smooth the output will be small, and the pulp will be fine and 'dusty' on the paper-making machine. Coarse stones give a greater output of longer-fibred pulp.

There are several kinds of mechanical pulp, named according to the method of grinding—viz. cold ground, hot ground, and cooked or steamed—*i.e.*

'brown'. Hot-ground pulp is that which is torn off the log in the presence of very little water, so that the contact point is made hot by the friction of the stone and the pressure employed. This hot-ground pulp is said to work less free than the ordinary cold-ground, but more difference is often observed between two consignments of cold-ground than between hot- and cold-ground pulp.

Cold-ground pulp is ground with a sufficiency of water to keep the stone



[*Boving and Co.*

FIG. 14.—BATTERY OF KAMYR GRINDERS

cool and carry off the fibres. The third quality is made from logs that have been steamed or boiled before grinding, and is a stronger-fibred pulp. About 25 per cent more power is required to grind the cooked logs.

The pulp fibres, after being carried away from the grinders, are put through strainers and over a *presse-pâte* machine or concentrator.

Any coarse particles which will not pass through the screen or strainer may be collected and re-ground.

After the web of pulp has been concentrated it is pressed and wound up on the top press roll until a sufficient thickness is obtained, when it is cut off, laid in a pile about 2 feet long by 18 inches wide and pressed in hydraulic presses for the removal of water. At this stage it contains about 50 per cent moisture, and it is usually exported in this state, ready to be made into paper.

Mechanical wood pulp is used chiefly in the manufacture of newsprint, of which it forms approximately 80 per cent; it is used also in the manufacture of cheap printings, poster papers, boards and wrappings. It cannot, however, be used alone, and must have a proportion of chemical wood pulp or other stronger fibre mixed with it, in order to carry it over the machine.

Owing to the impure state of the cellulose contained in mechanical pulp, papers made from it are gradually destroyed by oxidation, and they cannot therefore be exposed to light, air, or damp atmosphere for any length of time without being seriously affected.

The mechanical process is surprisingly successful in view of the direct transition from wood to pulp by the wet grinding of pulp wood blocks on abrasive stones. The grinder represents comparatively low capital cost, high production, and moderate conversion cost where power is cheap. This is a case where the best pulpwoods, such as spruce, have to be used for the cheapest process, with serious loss of fibre length, but with preservation of bright colour and cleanliness. The yield is over 90 per cent by weight of the dry wood and over 95 per cent if screenings are taken into account. It would appear that ground wood tonnages for world consumption will moderately increase with the use of still higher percentages in newsprint and for further use in board and low-grade printing papers.

To produce coarser fibres for insulation boards, hard-pressed board, and other rapidly increasing substitutes for lumber, it is possible to disintegrate wood waste by steam explosion, by dry shredding in hammer mills, by wet refining, or in the case of wood blocks by crude grinding.

The semi-chemical processes have not yet reached great importance, but much progress may be expected. Perhaps these pulps will not come into the trading market in large tonnages, for the same reason that groundwood is best adapted to direct conversion from slush pulp to the finished product. One need only mention the wide range between mechanical pulp yield at over 90 per cent and chemical pulp yield below 50 per cent to realise the future scope for medium cost pulps made by some combination of mechanical and chemical treatments. Reasons for the delay in development have probably been the low capacity and poor efficiency of refiners (compared with grinders for pulpwood blocks), the tendency to lose bright colour of fibre in the presence of weak chemicals, and the inherent difficulty of limiting the cost of a two-stage

process. At the upper end of the scale is the attempt to make the wood fibres flexible with minimum loss of yield. Longer fibres can be expected by progressive removal of hemi-celluloses and lignin in conjunction with mechanical separation of fibre bundles. High yields and cheap sources of wood are great incentives to develop grades of semi-chemical pulps suitable for various boards and papers.

Chemical Wood

The Sulphite Process.—The sulphite process dates back to about 1870 and was first used in America. The process consists in treating vegetable substances containing fibres with sulphurous acid in water, and heating them in a closed vessel or boiler under pressure. This action dissolves the incrusting matters which are bound up with the fibres, and a fibrous product is left, suitable for the manufacture of paper. During subsequent years several modifications of the original process were introduced, the chief among them being those of Partington, Ritter-Kellner, and Mitscherlich. The preparation of the wood must be carefully carried out; all rotten pieces, knots and blemishes have to be cut out and the bark shaved off, usually by hand.

Some fresh knots may be left in during the boiling, which has little or no effect upon them, and caught later in the screens. The cleaned and sorted logs are passed to the chipper, which shaves them into chips about 1 by $\frac{1}{2}$ inch. They are then carried on a travelling band and over a chip screen to the digester house, where they fall through hoppers into the boilers.

The wood used for each boil should be of the same kind and preferably of the same age. It is also an advantage that it should all contain the same amount of moisture. Green or freshly-cut wood is most easily reduced by the sulphite process. The wood in most general use is spruce or fir, though other coniferous woods may be used.

The boilers or digesters are built of steel, but on account of the corrosive action of the bisulphites and sulphurous acid a lining has to be added for protection. Innumerable experiments were tried, none of them very successful, to utilise a lining of lead, but now acid-resisting tiles or bricks and coatings of acid-proof cement are used.

The digesters are cylindrical in shape and for most processes they are vertical, although horizontal boilers are used in some cases. They are usually very large, 40 feet in height by 14 feet in diameter, or larger. They have manholes at top and bottom for filling and emptying.

They are heated by direct steam or, as in the Mitscherlich process, by steam coils made of lead, which are sometimes 2000 feet long. The digesters are

fitted with thermometer tubes, safety valves, blow-off cocks, etc., and also cocks for drawing samples of the liquor and pulp for testing purposes.

The bisulphite liquor for digesting the wood is made in the following way:

Sulphur or iron pyrites is burned in an oven with a carefully regulated supply of air. In this way sulphur dioxide gas is formed, which, after being cooled, is passed into the bottom of a tower, in which is stacked ordinary limestone. Water is made to trickle down and over the limestone, and the gas passing upwards mixes freely with it. The sulphur dioxide, or SO_2, is absorbed by the water, H_2O, and forms sulphurous acid, H_2SO_3:

$$H_2O+SO_2=H_2SO_3.$$

This solution acts on the limestone (carbonate of lime) to form sulphite of lime, water, and carbon dioxide:

$$H_2SO_3+CaCO_3=CaSO_3+H_2O+CO_2.$$

Ultimately bisulphite of lime is formed by the further solution of limestone. During the reaction free sulphurous acid is also formed, and it is this acid which is required for the reduction of the wood.

The sulphite process is largely confined to softwoods of low resin content. Notable advances are its advancement to pine of medium resin content, and its increasing application to hardwoods. From the chemical point of view the sulphite process represents a comparatively severe hydrolysis of the fibre in removing lignin and part of the lower carbohydrates from the wood. The pulp fibres are very flexible, but some strength is sacrificed. The great advantages are bright colour of the unbleached pulp for direct use and ease of bleaching, coinciding with the unconscious desire of the buying public for white papers. Particularly in Europe long experience in operation and widespread adoption of digester circulation has resulted in high quality of sulphite pulps. The yield of unbleached sulphite for paper-making usually varies from 45 to 50 per cent by weight of the chips, depending on wood species, bleachability, and other factors. This is a considerable range, amounting to 10 per cent difference in tonnage from the same weight of wood. There is no certainty that world tonnage of unbleached sulphite will materially increase, but bleached sulphite presumably will extend, for chemical uses in particular.

Here may be mentioned some of the modified sulphite processes. The Mitscherlich method of indirect heating and long cooking has become too expensive for general competition. The minimum change in the standard sulphite cooking liquor is the use of magnesium base in place of calcium base. Sodium bisulphite in America and Scandinavia is applied to resinous woods

or in relation to the purification of the final bleached fibre. The ammonium bisulphite process in Norway aids the recovery of valuable by-products from the spent liquor, and also has a bearing on the pulping of resinous woods. The sodite process in America employs alkaline sodium sulphite and yields a more distinctive grade of bleached pulp.

Soda Process.—In this process the chipped wood is boiled with caustic soda under pressure. No attempt is made to drill out knots or rotten parts of logs, as the soda process is so drastic as to eliminate these impurities. The resulting pulp is of a brownish shade, and does not bleach to so good a colour as sulphite pulp. The fibre is long, strong, and bulky.

Pulp from poplar, produced by this process, is very soft and absorbent. It is used in certain papers as a substitute for esparto and for cheap blottings.

This was the first chemical method of boiling pulp. The caustic soda treatment is satisfactory for aspen and harder deciduous woods to produce bleached filler fibres. Actually these mills are confined to America and are not expected to increase materially, because a greater number of sulphite and sulphate mills in the various forest countries can handle any hardwoods within reach. Yields are lower than by the sulphate process, which has the protective action of sodium sulphide.

Soda Sulphate or Sulphate Process.—This is simply a variation of the soda process. In the process of soda recovery, sodium sulphate is added to make up the loss of soda, and the liquor comprises a mixture of caustic soda, sodium sulphide, and sodium sulphate. This process has extended rapidly during recent years. The alkaline nature of the cooking liquor (caustic soda and sodium sulphide) makes it of universal application to all species of pulpwoods, including the very resinous. The trend is naturally towards the pines which grow both in northern and southern countries and which are subject to less competition than spruce. This means that sulphate pulp mills have the widest distribution, sometimes an advantage in proximity to markets. The special feature of the sulphate process is the ease of preserving the inherent strength of the wood fibres. The alkali resolves the bark and knot specks, and the shives to some extent are obscured by the brown colour of the pulp. The yields are close to those of unbleached sulphites, but tend to extend lower for easy bleaching sulphates. Total consumption of sulphate pulp has now reached half the sulphite tonnage, and promises to account for a larger proportion in future, perhaps chiefly for boards and in terms of bleached sulphate grades for many papers.

In connection with chemical pulp cooking processes there is a distinction to be noted between sulphite and soda in the mechanism of penetration. In the acid process the cooking liquor enters the chips almost entirely along the

grain of the wood, whereas in the soda processes the liquor is able to penetrate the chips in all directions.

After the pulping processes come the usual operations of riffling to settle out heavy impurities such as grit, and screening to separate knots, fibre bundles, and bark specks as carefully as possible. Kollerganging, rod-milling, or other light brushing treatment is often applied to kraft pulps. The coarser fraction

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FIG. 15.—TRANSPORTING LOGS INTO THE MILL

of mechanical pulp will benefit in strength and uniformity if present attempts to brush out the fibre bundles are successful.

Special mention should be made of fibre selection. Chemical pulps are sometimes treated to separate the longer, stronger fibres of higher purity. In the case of sulphite pulp, the removal of most of the pitch with the medullary ray fibres is also a feature.

The drying of chemical pulp over cylinders has been superseded in a number of mills by vacuum drying at low temperature in the absence of oxidising atmosphere, or by hot-air drying at comparatively low temperature, with a slight gain in ease of beating, brightness, and strength of pulp at the paper mills. Care in the baling of pulp for shipment has reached a high standard.

Bleaching and other chemical treatments of pulp may be looked on as processes of secondary digestion. Great advances have been made in recent years with the better knowledge of cellulose chemistry.

The bleaching of mechanical pulp is based on the reducing action of bisulphites or hydrosulphites, which brighten the yellowish colouring substances in groundwood without affecting strength or yield to any extent.

Chemical pulp bleaching has undergone revolutionary changes during the past ten years, based on laboratory methods known much earlier. The use of over half the total chlorine in the first stage for direct chlorination of the unbleached pulp at low temperature and consistency with thorough mixing, permits rapid formation of lignin products without appreciable change of the cellulose itself or reduction of shives and bark specks. Neutralising the hydrochloric acid formed in this reaction brings the chlorinated products into solution, and washing avoids the subsequent bleach consumption by coloured liquor left in a single-stage process. Second stage bleaching with calcium or sodium hypochlorite at low temperature and high density of pulp favours the oxidation of colouring matter and resolution of bark specks and shives under the mildest conditions. After again washing the pulp, a small percentage of hypochlorite brings up the desired whiteness under the best conditions for control. Caustic soda treatment, as a separate step or mixed with bleach liquor, is applied to dissolve hemi-celluloses. Acid treatment as a last stage reduces the ash content. It is perhaps superfluous to mention that numerous modifications of sequence, chemicals, and conditions are practised in both batch and continuous systems. The significant point is that multi-stage bleaching has yielded higher strength and purity of bleached sulphite pulps in relation to whiteness, and has permitted the economic bleaching of strong sulphate pulps for the benefit of the paper and board industry. The usual loss of fibre weight in the bleaching of paper-making grades is in the order of 5 per cent of the unbleached pulp—more or less depending upon the bleachability and other conditions—resulting in overall yields of 42 to 45 per cent from the wood to ordinary bleached sulphite.

Next comes the detailed grading of wood pulps. The dividing lines are not sharply defined because cooking degree, for instance, must be linked with strength figures; special characteristics are sometimes the determining factor, and uses overlap pulp qualities. It should also be remembered that grades are sometimes interchangeable—for example, semi-bleached sulphate serving in place of unbleached sulphite for certain papers.

Mechanical pulp grades may be named extra free, free, medium free, and slow. The drainage rates become progressively slower, due to increasing hydration and fineness of fibre. In general it can be said that the mechanical

pulps give maximum bulk, high opacity, good absorbency, comparatively low burst, low tear, and very low fold.

Extra free groundwood extends through the range from short coarse fibres of low strength, representing maximum production and economy of manufacture, to long flexible fibres of good strength, representing high cost of production. The board industry is perhaps the chief consumer, the desired properties being bulk and fold. The small tonnage of dry mechanical pulp for long-distance transportation is of this grade, as the fibre bonding properties are low enough to permit easy breaking up of the dry sheets, and there is fibre length to spare in the refining operation.

Free pulp is the standard grade for newsprint in this country. The strength should be as high as possible, and the shive content at a minimum. Comparatively high freeness is needed because the moist-baled pulp undergoes slight refining in the breaker beaters and jordans; the use of china clay further lowers the drainage rate on the Fourdrinier wire; and, furthermore, the sheet is rather high in basic weight. In self-contained mills converting direct from slush pulp, the free grade is usually made for boards and coarse papers.

Medium free groundwood is the general utility grade. Strength is higher, fibre size is more uniform, and the drainage rate is rapid enough for printing papers of various kinds, as well as for thin high-grade boards. The many self-contained newsprint mills in forest countries aim towards this grade for high-speed machines.

Slow pulp is a speciality for coating papers, telephone directory, tissue and other better-class groundwood papers. Freedom from shives and grit, best cleanliness, high brightness, and good strength are usually desirable, and the slow rate of drainage is unavoidable. Opacity is highest by reason of fine grinding.

Bleached mechanical is a special product which has reached some importance and may increase in future with the demand for cheap book and magazine papers. Pulp of the medium free grade is usually chosen for this after-treatment in the case of bale shipments, or slow pulp for the best possible printing papers made from slush stock. Uniform brightness, high cleanliness, and good strength are desired. Western hemlock is an example of a wood which yields mechanical pulp of reddish colour, and bleaching is sometimes practised to bring up the brightness to the spruce standard.

Semi-chemical pulps are not yet very important or definite as to grades, but the following comments will serve as examples:

Brown mechanical pulp, based on the steaming of wood blocks before grinding, is a border-line grade which might be classified with either mechanical or semi-chemical pulp. Although the pressure treatment is with steam only,

the process involves the extra step of softening in addition to grinding. The steaming results in a dark-brown colour which limits the use of the pulp to products of the leather board class. The drainage rate is in the range of very high freeness. The fibres are comparatively long and flexible, with much better tear than with ordinary groundwoods, and about the same bulk.

Various methods of heating pulpwood blocks under pressure with weak reducing liquors of the sulphite class have been tried to produce extra-strong groundwood of bright colour. The fibre strength approaches that of unbeaten sulphite, but the drainage properties tend to be slow. Cleanliness is excellent because the laundering of the blocks removes adhering dirt and brightens the exposed layers. Yields can be 80 to 90 per cent by weight of the dry wood, as the screenings are easily refined. This general grade gives promise of finding some economic use for low and medium grade white papers, and even suggests the possibility of a straight line process for newsprint mills by treating all the pulpwood without pressure.

In the intermediate range the most common example is short, brown, bulky fibre produced by mild alkali cooking of extracted chestnut chips followed by refining to brush out the fibre bundles for the manufacture of corrugating board.

Close to the border-line of chemical pulps is the quick cooking of southern pine at high yields for the manufacture of bulky kraft liner board. Only part of the inherent fibre strength of the kraft need be developed by the refining treatment, and the product does not require thorough brushing out of fibre bundles.

High-yield unbleached sulphite has recently been developed for use in the self-contained type of newsprint mill. The digester is blown before the fibres are thoroughly separated, and the washed pulp is brushed out in a modern type of refiner before going to the screens. Uniformity and cleanliness are not the highest, but unbeaten strength and bulk are satisfactory, and an all-over yield of 55 to 60 per cent means cheaper furnish.

Sulphite pulps are classified as unbleached, bleached, and semi-bleached. The general characteristics are excellent whiteness, quick hydration, medium strength, reasonable cleanliness, and low opacity of the fine flexible fibres.

Extra-strong sulphites represent minimum cooking to reach fibre separation and best possible strength. Careful screening has to be practised to reduce the shives and dirt. Depending partly on the wood, cooking can be adjusted to give either quick beating, maximum burst, and maximum tear. Ordinary uses are for M.G. papers and other extra-strong hard sulphite sheets.

Medium strong grades include many well-known brands of sulphite, and the uses cover a wide range. Brightness, uniformity, and cleanliness have

reached high standards. Not all the desired characteristics can be combined in any one brand, and this raises the general reminder (applicable to other grades also) that it is sometimes better to choose another brand instead of asking the pulp mill to depart from its established quality. The board pulps are usually tough in relation to heavy beating, comparatively high in fold and tear, and as opaque as possible. For printing papers, softness, high cleanliness, and good opacity are desirable. Newsprint sulphite for sale in the European market is much superior to the grade ordinarily used in self-contained newsprint mills; the trend towards softer fibre for better printing is also in the direction of higher cost at the pulp mills.

Greaseproof pulp is specially hydrated by cooking to develop good 'blister' at the end of the beating scale.

Bleachable sulphites in Europe range from about 14 to 20 per cent bleaching powder consumption by single-stage test. In this grade it is customary to hold the bleachability regular within reasonable limits, and two or three steps through the range are recognised. Cleanliness is a particular feature, because the pulp is so often to be bleached in single-stage plants. Strength naturally tends to decrease with lower bleach consumption.

Easy bleaching sulphite in Europe is still more carefully cooked and sorted for bleachability in three or four steps between 6 and 13 per cent bleach consumption. In America comparatively little sulphite is cooked below the 10 per cent figure except by the silk pulp mills, and the range up to about 18 per cent is known as easy bleaching. Cleanliness is again a vital factor because the small requirement of calcium hypochlorite cannot deal with excessive dirt. Unfortunately this soft cooking of sulphite distributes more specks from ingrowing knots through the pulp, but on the other hand these softer particles are more readily brightened by bleaching than in the case of stronger sulphites. It is worth noting that pitch troubles tend to decrease from extra-strong sulphite at one end of the scale, down to soft easy-bleaching sulphite at the lower extreme. Easy bleaching is particularly well suited to mix with esparto.

In Europe, several brands of easy-bleaching aspen sulphite are available for bleaching at the paper mills. Another hardwood sulphite in this range is eucalyptus.

In the range of semi-bleached sulphites there are not many examples. It is a question whether the pulp mills should develop a grade from strong sulphite for direct use in the semi-bleached state, because bleaching to yellowish colour consumes most of the bleach sufficient to reach high white colour and the strength does not approach that of semi-bleached kraft. Recently the idea has been modified to supply an easy bleaching sulphite of much better strength

than can be reached by soft cooking, this being accomplished by starting with bleachable pulp.

Strong bleached sulphites include several varieties. Tough papers and boards may call for fibre of yellowish-white colour which will stand up to heavy beating. Bond pulps are adjusted to fairly quick beating and high burst. Multi-stage bleaching has extended the range to the bleaching of comparatively hard sulphites, and in general has given better strength and purity at a given whiteness, as well as yielding whiter pulps of excellent stability compared with earlier days.

Soft bleached sulphites are ordinarily used for book, magazine, and other printing papers. High-white colour, high cleanliness, good bulk, and opacity become more important than strength. This is the type of pulp which the pulp mills with older equipment can continue to make. Speciality qualities are made for genuine vegetable parchment, photographic papers, absorbent tissues, and other uses with control of highest whiteness and cleanliness, low pitch, low content of iron and copper, low ash, etc.

Bleached hardwood sulphites have been coming into more prominence. In Europe, bleached aspen sulphite of excellent whiteness, cleanliness, and fineness of fibre has been supplemented by bleached beech. In America bleached hardwood sulphites made from birch, beech, and maple are on the market to give much better strength and quicker beating than with bleached soda pulp.

Silk pulp for viscose rayon staple fibre and viscose films has reached such a large tonnage that it has become almost an industry in itself. The brands of the older type are not very different from soft bleached sulphites made for paper-making, except that greater care is taken to control viscosity and good swelling characteristics in caustic solution, and to reduce resin, ash, and other impurities. The use of alkali and other special treatments has resulted in a higher grade of silk pulp with over 90 per cent alpha-cellulose content, less degradation of the cellulose, better whiteness in alkali, and extremely low impurities for conversion to stronger, brighter thread in the modern rayon mills. This grade also involves special control of sheet size, moisture content, basis weight, thickness, and absorbency. Although this grade has been largely made from spruce and western hemlock sulphite pulps, there is a distinct widening of the scope to include sulphite and sulphate pulps from pine and hardwoods.

'Alpha' pulps of alpha-cellulose content well above 90 per cent are specialised in their characteristics and limited in their sources of production. Sulphite and sulphate pulps from softwood and hardwoods are given special treatments in addition to bleaching. In the range up to about 95 per cent

alpha-cellulose, the further removal of pentosans, oxycellulose, and hydrocellulose tends to raise the whiteness, stability of colour, cleanliness, chemical purity, permanence, tear, softness of fibre, and resistance to hydration. Softwood sulphite fibre is very suitable for high-grade bond, parchment, and other strong papers, and the beating characteristics become closer to those of rag stock. Hardwood fibre of exceptional softness, bulk, opacity, and brightness is used in mixture for fine-textured papers and boards. Sulphate fibre at moderate whiteness gives the toughest high-grade products. In this range also are purified pulps designed for photographic paper, absorbent tissue, moulded products, and high-grade viscose.

The scope of sulphate pulps has been greatly extended by including bleached grades in addition to unbleached and semi-bleached. As is well known, the general characteristics are high strength, resistance to beating, freedom from pitch, relatively high freeness, and colour varying from dark brown to good white. It should be remembered that not only are breaking length and burst of sulphate pulps superior to the best that can be reached with sulphite parallels, but also the tear and fold are outstanding. The properties of sulphate are more standard for each grade than in the case of sulphite, because the alkali cooking has a more specific action on the wood fibre with less hydration of cellulose and pentosans.

Unbleached grades include kraft, light and strong ('L. & S.') kraft, easy bleaching, and aspen sulphates, according to the usual European classifications.

Kraft pulp is the well-known, extra-strong brown fibre used in the toughest grades of paper and board. The best brands for fine wrapping papers and tissue must be cooked for a fairly long period from fine-fibred woods such as northern pine or spruce to reach the stage of well-separated fibres. Fairly long beating time must be expected with kraft pulps.

Light and strong kraft represents somewhat softer cooking to reach brighter colour. The tear is high, but the fibre has lost some of its bursting strength.

Speciality grades made from kraft or 'L. & S.' kraft include pulp which has received chemical treatment and thorough washing to reduce the electric conductivity to a very low figure for the manufacture of condenser tissue, and pulp which has been treated to swell the fibres for use in absorbent products such as roofing felt.

Easy-bleaching sulphate is reached by more thorough cooking to yield pulp which will bleach by single-stage treatment with 12 to 18 per cent bleach. Bleached in this way, the final colour cannot be expected to equal the whiteness of bleached sulphite, but the high tear, good bulk, and good opacity are very useful for soft printing papers.

Easy-bleaching aspen sulphate is an example of short-fibred hardwood pulp for sale to paper mills having their own bleaching plants.

Semi-bleached grades may become more important as time goes on. Present methods make it much easier to reach yellow colour with sulphate than to attain the high whiteness of bleached sulphite, and very little strength is lost.

Semi-bleached kraft represents the initial stages of chlorination and hypochlorite treatment applied to the best brands of strong kraft. This grade is intended for the toughest papers of manilla colour as a substitute for rope and hemp. The fibre has maximum strength, is less harsh than kraft or bleached kraft, and lends itself to a wide range of beating.

Semi-bleached 'L. & S.' kraft is a softer grade. This is the kind of pulp which may be economically made from southern pine to compete with unbleached sulphite.

Semi-bleached soft sulphate may be a suitable name for easy-bleaching sulphate which has been given preliminary single-stage bleaching. In this case the pulp can be readily bleached at the paper mills to give better bulk, opacity, and tear than is possible with easy-bleaching sulphite.

The most important advance has been made by the application of elaborate multi-stage bleaching to sulphate pulps, with the result that good white colour is reached without serious loss of strength properties.

Bleached kraft is the greatest achievement, and a number of well-standardised brands are now available, mainly from the northern districts of Europe and America. Colour equal to that of strong bleached sulphite is available if maximum strength is not required, or a slightly yellowish colour can be obtained with strength characteristics approaching those of kraft. Opacity of bleached kraft appears to be much the same as with strong bleached sulphite at equal freeness of fibre, but higher at equal strength of sheet. Fortunately, in beating time and power consumption, bleached kraft is intermediate between unbleached kraft and strong bleached sulphite. Although the fibre can be successfully mixed with sulphite in the beater, separate beating naturally gives better results whenever convenient. The fibre tends to give fuzz and inferior sheet appearance with ordinary light beating, but sharp tackle and heavy roll improve the texture and opacity without seriously affecting the burst and tear of the sheet. Longer beating increases transparency and toughness, and the treatment can be continued to a very high end-point of bursting strength without losing too much tear or freeness. Filler fibres such as bleached hardwood sulphite can be mixed with bleached kraft to improve formation, surface appearance and opacity without undue loss of strength. Experience with bleached kraft can conveniently be gained by using various proportions

with bleached sulphite or rag stock in present products being manufactured at a paper or board mill. Bleached kraft by itself is ideally suited to extra-strong tough papers which hitherto it has not been possible to make from wood pulps. Progress will undoubtedly also lead to the development of specialities which have not been economic with rag or hemp.

Bleached 'L. & S.' kraft is a name chosen for the slightly softer grade. At yellowish-white colour the strength should approach that of bleached kraft. The usual aim is best possible whiteness, with appreciable decrease in burst and fold. The fibre is somewhat finer in texture, softer and more opaque than that of bleached kraft, making it competitive with strong bleached sulphite for various papers and boards.

Soft bleached sulphate is the grade made from easy bleaching sulphate. Single-stage bleaching does not produce high white colour, but the brightness can be raised close to that of bleached sulphite by multi-stage treatment. Opacity is very high. Softness and absorbency are also high. In addition to paper and board competition with soft bleached sulphite, this grade may be expected to take a share of the chemical uses after suitable purification.

Bleached aspen sulphate is the corresponding grade of short-fibred pulp. Other hardwoods will also find a place in this grade.

Bleached soda pulp is the well-established grade in America, based on caustic soda cooking and bleaching of hardwoods for mixing with soft bleached sulphite in papers of the book and magazine type. The brightness is comparatively low. The fibre is soft and bulky, and the pulp resists hydration to maintain freeness, very good opacity, and low shrinkage.

Bleached soda pulp is perhaps the nearest wood pulp approach to esparto, although the latter has superior burst, tear, opacity and fineness of texture.

A variation of the soda process is sometimes practised by mixing only a small proportion of sodium sulphide. In this way there is an appreciable gain in strength over the regular soda process, and the bulking properties are better than in the case of sulphate pulp. Softwoods are sometimes cooked in this way for bleaching purposes.

Pulp Qualities

Uniformity is the first on the list of quality requirements for all pulps, regardless of process or grade. This refers to evenness of fibre qualities demanded by the particular use for which the pulp is needed. It applies not only to the regularity of quality from one shipment to another, but also throughout a bale or batch. For instance, in a self-contained newsprint mill one of the main technical problems is continuous control at the grinders, of

freeness, strength, and running properties of the mechanical pulp, because uniformity means so much on the paper machine for high speed, fewer breaks and steady quality of newsprint.

In a mill using purchased pulp smooth operation is greatly aided by being able to rely on the running properties of a brand. The difficulty of controlling uniformity is a story in itself. Remembering the variations in wood, seasonal conditions, and the many other factors in a pulp mill, the problem of ending up with uniform pulp can be readily appreciated. Modern pulp mills have elaborate organisation of staff and instruments towards this end, and it is a tribute to their efficiency that pulp for sale is nowadays a remarkably uniform product.

Cleanliness is also an item of vital importance in relation to most grades of pulp. The very fact that paper and board meet the eye naturally brings cleanliness to the front. The main problem of dirt is in unbleached sulphite pulp, due to black knots softening in the acid process and spreading through the pulp. Great precautions are taken to clean the wood as carefully as possible, to blow the digester gently, and to remove the larger dirt particles by settling and screening. Circulation in the digesters has helped to remove shives and dirt. The mills are not resting content with the present methods, and there is some hope that a centrifugal separation of dirt will prove economic. In the case of groundwood, ordinary dirt is seldom criticised because the mechanical process has the advantage of finely grinding the hard knots and other discoloured parts of the wood, but the shives and small fibre bundles are naturally prominent because of the very nature of the process (grinding process). Sulphate pulps gain by the cooking liquor digesting the knots and bark specks, leaving shives as the main item. Grit or metallic particles may find their way into mechanical pulp from the grinders, into sulphite pulp from the digester linings, and into pulp in general from wood, piping, and other sources. The fact that pulp bales pick up extraneous dirt during transport and storage adds to the demand for extra-clean pulp sold in the open market, especially as the paper machine screens are mainly for protection of the Fourdrinier wire.

The general demand for whiteness and brightness has led to much attention along the lines of colour control. The brightness of unbleached sulphite and kraft has been improved by studying the cooking conditions. Multi-stage bleaching of chemical pulps has produced whiter products of wider range. Furthermore, the chemical purity and stability of the bleached pulps are higher, giving better resistance to light and heat. The colour after waxing depends on the physical and chemical nature of the fibre as well as on the apparent colour of the pulp. Pulp for rayon must retain good white colour in caustic soda. An extreme case is the need for highly purified chemical pulp

for high white plastic products. In the field of ordinary paper and board the colour after beating must also be considered.

Strength, breaking length, burst, tear and fold are very useful in controlling the uniformity of cooking and bleaching. Breaking length and burst may be said to depend mainly upon the fibre-bonding properties developed by the process. Tear depends more on fibre length. The cooking process has an important bearing on tear, kraft being inherently much stronger than sulphite. Fold, though hard to measure accurately, gives a further insight into the chemical effects of cooking and bleaching. It is always well to remember that burst and tear develop in opposite directions in both the cooking and beating processes, which means that attention should be paid to the overall strength of a pulp.

Beating does not concern mechanical pulps to any extent, but the grinding process is really a form of beating to develop hydration and fibrillation of the fibres. Unbleached sulphite pulps can be controlled by the cooking process within limits to give quick or slow beating as required. Sulphate cooking is flexible in this respect, and in general the pulp requires more beating time and power. The bleaching operation can be considerably varied in relation to beating properties, the use of caustic soda in the second stage being a modern example of improving the resistance to hydration.

Fibre size, opacity, porosity, absorbency, oil penetration, blister, bulk and other characteristics can be controlled within limits both in pulp mill and paper mill.

Moisture content is a question which does not arise in self-contained mills using slush pulp. In the case of pulps for shipment the problem is largely an economic one. Mechanical pulp does not lend itself to drying, except the free grades for board-making. Unbleached sulphite and kraft pulps shipped in the moist condition break up more easily and beat more quickly to somewhat higher burst, but suffer to some extent from danger of picking up dirt and of developing infection. Dry pulp is an advantage for long storage, better opacity, and more uniform control. Bleached pulps, except for greaseproof and a few other uses, are shipped in the dry condition to ensure best cleanliness and brightness.

Ash content tends to be high in sulphate pulps, but is not of particular significance. The ash in sulphite is largely due to calcium compounds precipitated during cooking or bleaching, and when necessary can be reduced by acid treatment, as is practised with bleached grades for chemical uses. Pitch content has been given thorough study in the pulp mills. Mechanical pulps seldom give running trouble, because the normal character of the wood resin has not been altered by the grinding process. Sulphate and soda pulps are

practically free from resins by reason of the alkaline cooking. Unbleached sulphite is the chief problem, because the acid cooking makes the pitch more sticky. Great precautions are taken to avoid harmful character of pitch and to lower the percentage in the pulp. The bleaching process greatly reduces the pitch content. For chemical uses the bleached sulphite is treated with alkali and sometimes with saponifying agents to remove practically all the resins.

Small quantities of foreign matter have sometimes to be controlled for special uses. Iron and copper, either in specks or in diffused form, must be kept to low figures in bleached pulps for the manufacture of photographic paper, genuine vegetable parchment, and other special grades. Chemical pulp mills are using more and more glazed tile, stainless steel, rubber, and other resistant surfaces to avoid impurities. Sulphur residues must be reduced below specified figures in sulphite and sulphate pulps for anti-tarnish paper and similar products, but groundwood is naturally pure in this respect.

The reddening of unbleached sulphite is due to oxidation of colouring bodies, and the tendency towards reddening may be judged by testing with hydrogen peroxide. Reddening is usually greatest with strong sulphites and least with easy bleaching grades, but the wood species and the pulping conditions also have a bearing. Reducing agents, such as sodium thiosulphate, have a protective action.

Reduction of Esparto Grass to Half Stuff

The bales being opened out, the grass is put through a willow or duster similar to a threshing machine, which breaks up the bunches and loosens and separates the sand, dust, etc., from the blades. From the duster a conveyor carries it to the boiler. The boilers are usually of the stationary vomiting type. A revolving boiler causes too much loss of fibre through friction, and packs the grass into hard heaps very difficult to deal with. A usual size holds about 2½ or 5 tons of dry grass. Boiling is conducted with about 14 to 15 per cent caustic soda, from 3 to 4 hours, with 40 to 60 lb. steam pressure, depending upon the quality of the grass and the capacity of the boiling plant to keep up with the demands of the mill.

The caustic liquor is run in with the grass, and some steam turned on in order to soften it and get a heavier charge into the boiler. On the completion of the boil, the steam is blown off and the used liquor is run to the recovery plant. Further washes with hot water to remove the last of the liquor are necessary, and these may also be run to the recovery plant or liquor tanks. The grass is then dug out and filled into trucks, or it may be more conveniently

cut out by a high-pressure water jet and washed, blown or pumped to the washers or concentrator.

Washing and bleaching follow the same lines as for rag, but the potchers have no plates, and the blades are blunt and waved, so as to prevent any cutting or drastic beating taking place. Even then a very great loss of fibre takes place in washing and bleaching through the washing drums; about 7 per cent bleach is used and heat is permissible up to 90° F. Very dull-coloured stuff may with care be heated up to 100° F., but the risk of destroying the fibre is very great, and only highly experienced men may be allowed to take it.

Spanish esparto requires less bleach to bring up the colour. From the potchers, after the bleach has been washed out and the last traces have been killed with anti-chlor, the pulp is emptied into the *presse-pâte* chests. The *presse-pâte* is the wet end of a Fourdrinier machine. There are long and deep sand traps through and along which the grass flows with the water, loosening sand, metal or any other heavy substance that may sink and be caught by the felts on the bottom. Sufficient strainers to take the pulp through without forcing are provided. These keep back all knots and thick untreated fibres and lumps. The wire, of rather coarse mesh, then receives the pulp, and the water drains out, assisted by the suction boxes. After passing the couch rolls, the water is still further extracted by a felt and press rolls, and the pulp falls into boxes ready for the beaters, or may be conveyed to the beater chest. The yield of fibre varies according to the country of origin of the grass and other factors, but it may be taken to be from 38 per cent for Oran grass to 45 per cent for best Spanish. The amount of bleach required is usually between 7 and 10 per cent calculated on the weight of the raw grass.

STRAW

Up to the present time, in Great Britain, at least, it has been the custom to treat straw in much the same way as esparto—namely, to boil it in stationary boilers with caustic soda, then wash in tanks of potchers, bleach and run the fibres over a *presse-pâte*.

Boiling is carried out at from 20 to 80 lb. pressure per square inch, with from 10 to 20 per cent caustic soda, according to whether yield or colour is more important. When the boiling process is drastic, the yield is small and the pulp is capable of being bleached very white, but its strength is greatly reduced, and it produces a 'wet' condition in the furnish owing to the formation of oxycellulose.

The straw may be cut up in a chaff-cutter or packed into the boiler in bundles. It is best, however, to cut it up, as dirt is then much more easily loosened and dusted out. It is unnecessary to remove the knots from the straw stems before boiling, but in order to free it from corn and hard particles of grit, etc., it is cut into short lenghts of 1 to 2 inches and blown through a trunk into a hollow gauze chamber. The heavier particles remain behind and fall through the gauze, while the lighter straw passes on and is filled into the digester. After the digester is full, or while it is being filled, the straw is soaked with water or with caustic solution in order to pack it down. The digester is then filled up again with more straw, and the boiling commenced. The pressures employed vary from 20 to 80 lb. per square inch, and the caustic soda from 10 to 20 per cent. The resulting stuff is a pulpy mass which can be run through pipes to draining tanks, whence the lye is drained away for recovery, and fresh water is run on to the pulp to complete the washing. After draining, the pulp is dug out, bleached in potchers, run off on a *presse-pâte*, and is ready for furnishing to the beater.

Another method, which, however, is very wasteful of small fibres, is to wash the boiled straw in ordinary breakers with drum washers. The wire cloth covering of the drums in this case must be of very fine mesh in order to retain the smaller fibres and cells.

We are indebted to Mr. B. A. Poulie Wilkins, Managing Director of the Stroostoffabriek 'Phœnix', Veendam, Holland, for the following particulars of the treatment of straw for making fine writing papers:

> 'The straw is cut into short pieces about an inch in length, and is then boiled in rotary boilers with sulphate liquor of about the same constitution as the liquor used for boiling kraft sulphate pulp. After cooling, the contents are blown into washing tanks for the separation of the stuff from the black liquor. The stuff is next run through a refiner into the bleaching tanks, where it is treated with about 1 per cent of chlorine. It is then run off on a pulp-drying machine and is ready for use.
>
> 'The black liquor from the washing tanks goes to the soda recovery department, first to the quadruple-effect evaporators, where it reaches a strength of 25° to 32° Baumé; the rotary furnace fully dries the black mass, and this material is burnt in the smelting furnace to Na_2CO_3 and the Na_2SO_4 is reduced to Na_2S; the causticising plant does the rest.
>
> 'The composition of the straw itself is of vital importance, and also its state of cleanliness. In this country [Holland], for instance, the examination of stalks of rye straw has revealed that those grown near the North Sea—that is, on the land which contains a very high percentage of silicates

—contain as much as 5 per cent by weight of silicate. Straw grown on average soil contains only about 0.5 per cent.

'From this it will be realised that raw materials varying so much in composition require different treatment. Great difficulty is experienced in the soda recovery department when dealing with the waste liquors from straw containing a high percentage of silicates, on account of the formation of sodium silicate on the melting furnace.'

Excellent writing papers may be made from straw pulp manufactured by the above method, in the furnish of which as much as 80 per cent of straw is included.

At present there is a tendency to move out of the old rut in the preparation of raw materials for making white papers, and to carry out the boiling and bleaching on more scientific lines, and to take advantage of the advances in the knowledge now available so far as the chemistry of cellulose is concerned. Two processes have been largely developed in recent years, mainly for the production of bleached pulp from raw materials such as straw, hemp, flax, and other plants and grasses. The first of these was developed and put on to a commercial basis by De Vains, who originally applied his methods to producing satisfactory pulp from straw about twenty-five years ago. This process has been further developed, and now Professor Pomilio has also developed a process on rather similar lines, which seems to have met with some success in various parts of the world. Both these processes rely to a great extent on chlorine gas acting upon the moist pulp and removing the lignin. Satisfactory results have been obtained by both processes, but there are a certain number of difficulties to be contended with in each case.

CHAPTER VI

BEATING

Beaters — Beating — Refining

The beater may perform several operations besides its chief function of actually fibrillating the stuff.

First, it may have to break up sheets of wood pulp or lumps of rag stuff. This is done by feeding in or furnishing the sheets or lumps of stuff gradually after the beater is about half or three-quarters full of water.

The sheets of wood pulp should be wetted first, or pushed under water before they reach the roll, in order that they may be as soft as possible. In the same way the lumps of rag half stuff, which are usually damp, should be torn up small by hand as they are being thrown in.

During this period of furnishing the roll is raised up well away from the plate, to prevent it jumping up when any hard lump of stuff comes between it and the plate.

In a surprisingly short time the sheets of wood or lumps of rag are reduced to a fairly uniform pulpy mass. In the case of the rag stuff, the first treatment depends to a great extent on how far the rags and threads have already been reduced in the breaker. Usually, however, a great many twisted cotton threads are still present, and these have to be drawn out by the roll.

As soon as this is accomplished the beating proper begins, and the roll must be let down to a fairly hard rub. Just how much pressure can safely be brought to bear on the stock depends on the strength of it when it is furnished, and this must be left to the skill and experience of the beaterman. When the beating has been carried far enough, and it is found on examination that the fibres on the whole are too long, the roll must be let down heavily on to the plate for a short time to cut some of the longer fibres to a length suitable for the paper which is to be made.

Finally, the stuff must be cleared—that is, the little clumps and knots of fibres must all be separated out—otherwise hard lumps may get through, and may either clog up the strainers or, if they are small enough, find their way into the finished sheet.

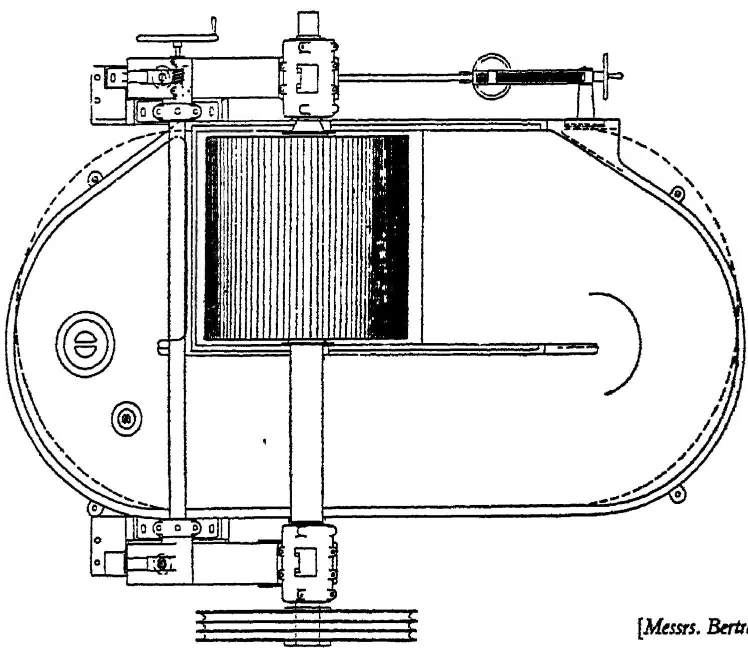
The treatment of wood pulp is much the same as rags, except that there are no threads to be drawn out; nothing but small clumps of fibres have to

be separated out before the actual beating begins. There is also much less cutting or reduction of the length of individual fibres, as they are much shorter than rag fibres to begin with.

The final clearing of knots and the reduction of the longer fibres to a uniform length are often performed by a refiner or perfecting engine. This is invariably the case in the beating of newsprint and cheap printings, and in most cases where the object is to get the beaten stock as 'free working' as possible.

Beaters

There are a great many different designs of beaters in general use, but these may be divided, broadly, into two classes—viz. those which depend for the



[*Messrs. Bertrams Ltd.*

Fig. 16.—Plan of Sciennes Patent Hollander Beater, showing the Well-Designed Shape of the Trough, which eliminates Dead Spots and aids Circulation

circulation of the stuff on the beater roll itself, and those which have a separate circulating apparatus, either pump, screw or propeller.

The first named are the most universally employed, and in fact they are entirely satisfactory for making all kinds of paper. The second group are used for those fibres which are not liable to form strings, and they find favour with some paper-makers who use a large proportion of esparto grass.

The first and foremost of all beaters is undoubtedly the hollander (Fig. 16), which is, so far as is known, the first advance which was made on the 'stampers', and it was, no doubt, originally invented when the necessity arose for

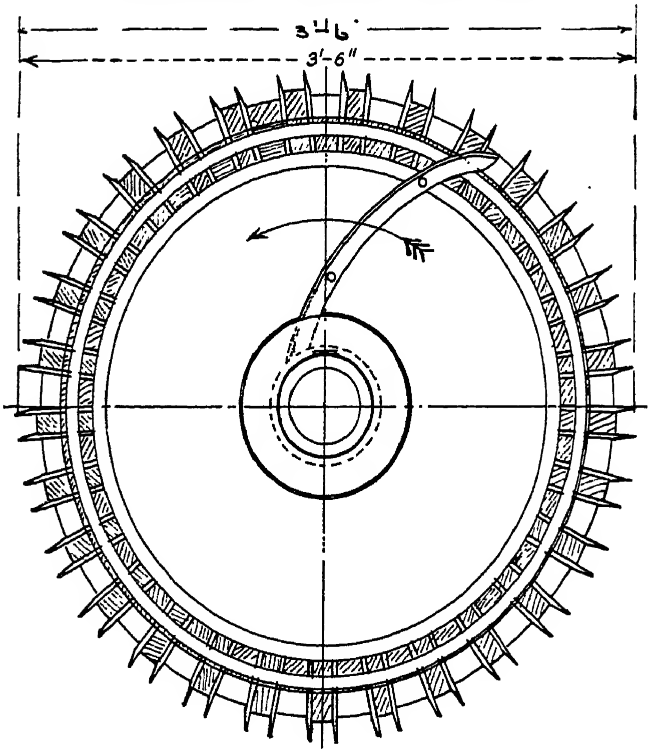


Fig. 17.—Beater Roll, Front Elevation, showing Bars arranged in Clumps of Two

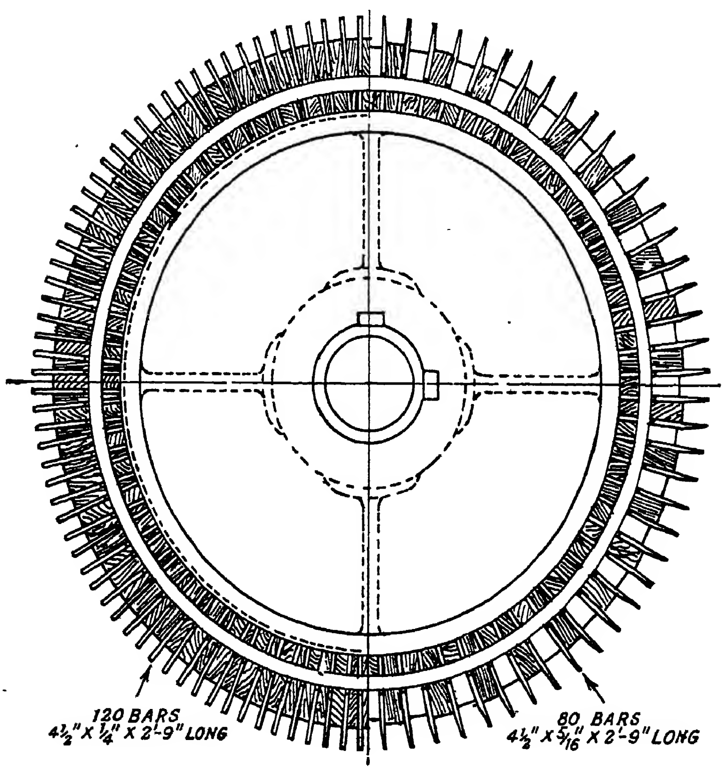


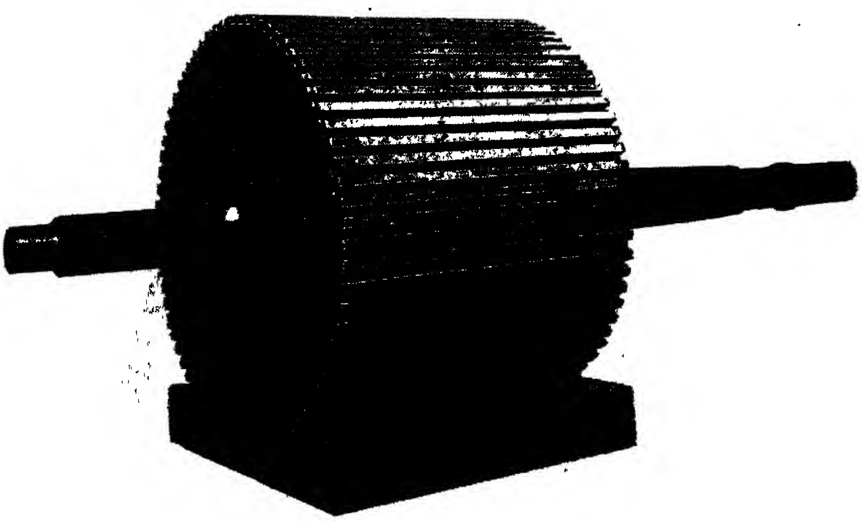
Fig. 18.—Elevation of Beater Roll, showing Two Methods of Filling

All bars are equally spaced, those on the left being closely grouped to allow 120 bars to the roll $\frac{1}{4}$ inch thick. The filling on the right allows for 80 bars bevelled to $\frac{5}{16}$-inch

greater output. This engine enabled the beating to be carried on continuously, on a fairly large body of stuff, in quite a small area; whereas only a few rags could be pounded at one time in the stamper trough, which was a very slow business.

The hollander consists of a large oval trough with a partition, called the midfeather, dividing it for some distance down the middle, but stopping short a few feet from each end. The plan (Fig. 16) shows clearly the shape of the trough and the partition.

The trough may be of cast iron, wood or concrete, and may be lined, in the case of cast-iron and concrete types, with cement, glazed tiles, lead or



[*Bertrams Ltd.*

FIG. 19.—BASALT LAVA BEATER ROLL WITH CAST-IRON SPIDER AND STONE SEGMENTS

copper. The construction of the trough is such as will permit and encourage the quick and regular circulation of the stock, and prevent the lodgment of any stuff, which might thus escape proper and thorough treatment, and which, getting emptied down into the chest with the water used to wash out the beater, would spoil the paper or seriously clog the strainers. The presence of sharp corners, hollows or projections in the trough is very undesirable.

The beater roll (Figs. 17, 18 and 19) is placed on one side of the midfeather, about midway between the ends, and consists of a cast-iron or iron and stone cylinder, through which is fixed a steel shaft, which serves to support the roll and also to connect it, by means of a suitable pulley, to the main driving shaft.

A modern development is a roll driven by an internal electric motor which

does away with indirect drive and saves much room. This arrangement has another desirable feature in that it eliminates the driving belt which may upset the alignment of roll and bed-plate.

The roll can be raised or lowered on to the bed-plate at will by means of a lifting gear attached to the bearings, and operated by a wheel or handle through a fine adjustment screw.

The iron roll is cast with alternate longitudinal projections and spaces, or grooves, around its circumference. The grooves serve as a housing for the flybars, and are about 4 inches wide. There is also a channel left round each end of the roll into which fits the iron ring used to hold the bars in place.

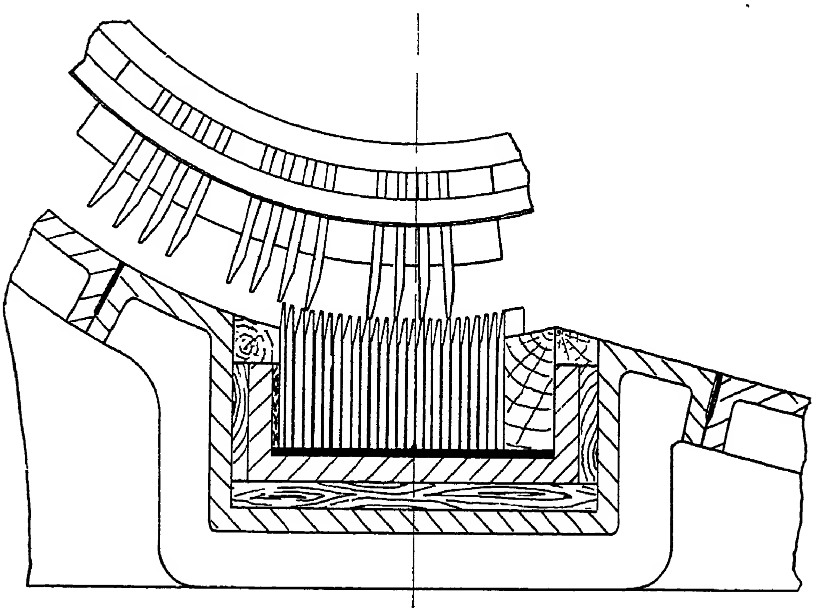


Fig. 20.—Front Elevation of Bed-Plate and Section of Roll, showing Roll Bars arranged in Clumps of Four and Bevelled

The flybars may be of steel, bronze, or other alloy, and they are usually arranged in clumps of two, three, or four, although there is no reason why they should not be equally spaced around the roll. When arranged in clumps, the bars are usually about 1 inch apart, and the clumps are about 4 inches apart. The idea of leaving a space between the clumps is to make the first bar of the clump act as a paddle to pick up stuff and carry it down into the nip between the plate and the roll (Fig. 20). No doubt this arrangement of the bars increases the speed of the circulation, but it does not necessarily follow that more fibres are treated in proportion to the increase of speed. In fact, some consideration will show that the increase in circulating speed means that so many more fibres pass untouched by the bars and plates. The bars may be sharp at the edges, and bevelled down to $\frac{1}{16}$ inch for beating free stuff, such

as blottings, filter-papers and thick papers required to bulk well, or they may be broad and blunt ($\frac{3}{8}$ inch), as for strong rag papers, thin banks, etc. The basalt lava stone roll (Fig. 19) has no bars and does not cut the fibres. It is used chiefly on wood-pulp furnishes for making very 'wet' and highly fibrillated stock for greaseproof and kraft papers.

Immediately below the roll, in the floor of the beater trough, is a sunken box, or 'den', into which fits the bed-plate. This consists of a heavy baulk of timber or a cast iron tray into which is fitted a set of metal bars or knives, similar to the flybars of the roll. This bed-plate (Fig. 21) is fixed, and the knives in it are so arranged that the flybars meet them at a slight angle, in order that their action on the fibres may be a shearing or tearing process, and not a direct cut or chop. This is effected by placing the knives diagonally across the box, or, more frequently, by having them bent into an elbow shape as shown in the illustration. This latter arrangement of the bars, besides giving a shearing action, also performs the important function of taking some of the fibres from the inside to the outside of the trough and so mixing them continuously, and thus preventing those on the inside from continually circulating round a much smaller area than those on the outside. It should be noted, in this connection, however, that the fact that the stuff near the midfeather makes a complete circulation more frequently than the stuff round the outside edge of the trough has the great advantage that all the fibres are not reduced to approximately the same length, and thus a much better and closer felted paper can be made.

Just beyond the bed-plate is the 'backfall', which is a continuation of the trough of the beater, carried up in the form of the arc of a circle, to correspond with the circumference of the roll, and close to it.

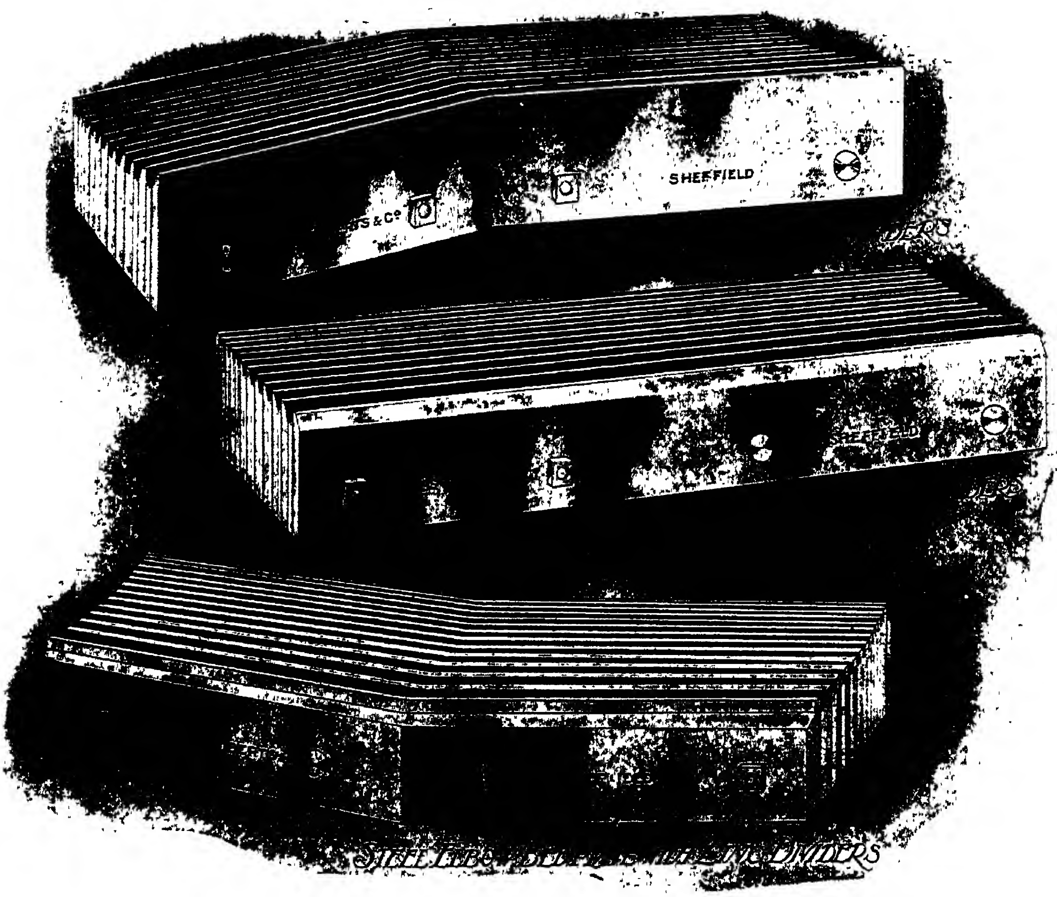
The backfall should be about $\frac{1}{2}$ to 1 inch away from the roll when it is 'down', and carried well up to about 3 inches above the centre of the shaft, tapering away from the roll at the top until it is about $2\frac{1}{2}$ or 3 inches away, thus leaving no pocket of dead stuff at the top. These dimensions are clearly shown in the accompanying illustration.

These measurements give the best circulation and fibrillation of high-grade wood pulp and rag stock; if the distance between the roll and the top of the backfall is great, there will be a heavy pocket of stuff lying dead and impeding the flow of stuff coming away from the roll. It is important that the backfall should be close to the roll, in order that there may be as much friction and rubbings of the stuff as possible during its passage from the bed-plate to the top of the backfall, where it is thrown out into the trough again.

The fact that the bed-plate bars wear down, however, makes it impossible to have the roll always at the same distance from the backfall, unless the roll is stationary and the bed-plates are hydraulic, so that the distance must be so

arranged that when the bed-plate is worn right down the roll will be about ½ inch away from the backfall.

Another point of importance in the design of the trough is the amount of rise from the lowest level at the emptying valve to the plate. Some beaters are quite flat and have no rise at all, and in this case the roll is deeply submerged



[*Messrs. Crookes, Roberts and Co.*

Fig. 21.—Various Shapes of Beater Bed-Plates

in the stuff and whips it continuously, without taking any more stuff through between the plate and the roll bars.

This whipping, while doubtless aiding the fibrillation of the stuff, consumes a great deal of power, and has the disadvantage of heating the stuff too much for all the fibrillation it accomplishes.

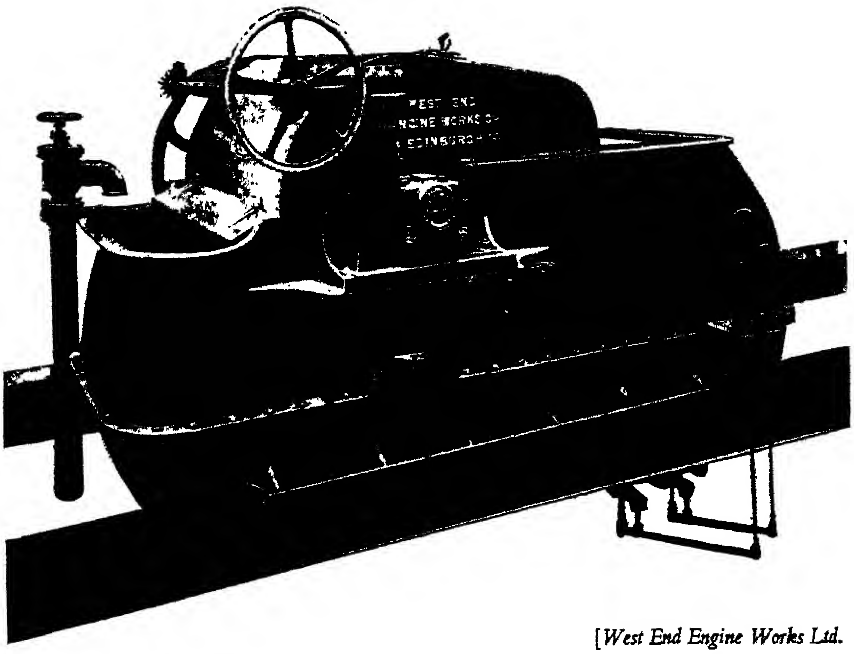
Our experience with beaters of this type has convinced us that their circulation is very poor, and that the continual whipping of the stuff dulls the colour and spoils the purity of the paper.

We have described our ideas of a hollander beater in some detail, but

experience shows that if the maximum efficiency is to be obtained, great care must be paid to details of design and dimensions.

For a hollander holding 450 lb. of dry stuff and intended for general use, such as the beating of wood pulp, wood and 'broke', wood and rag and all rag furnishes, the weight of the roll should not exceed 3 tons and the circumferential speed of the roll should be about 2000 feet per minute.

The Umpherston beater (Fig. 22) differs from the hollander in that it is placed 'on end' to save space; in other words, the stuff travels down from



[*West End Engine Works Ltd.*

FIG. 22.—UMPHERSTON BEATING ENGINE

In this type of engine the stuff circulates in a trough beneath the bed-plate

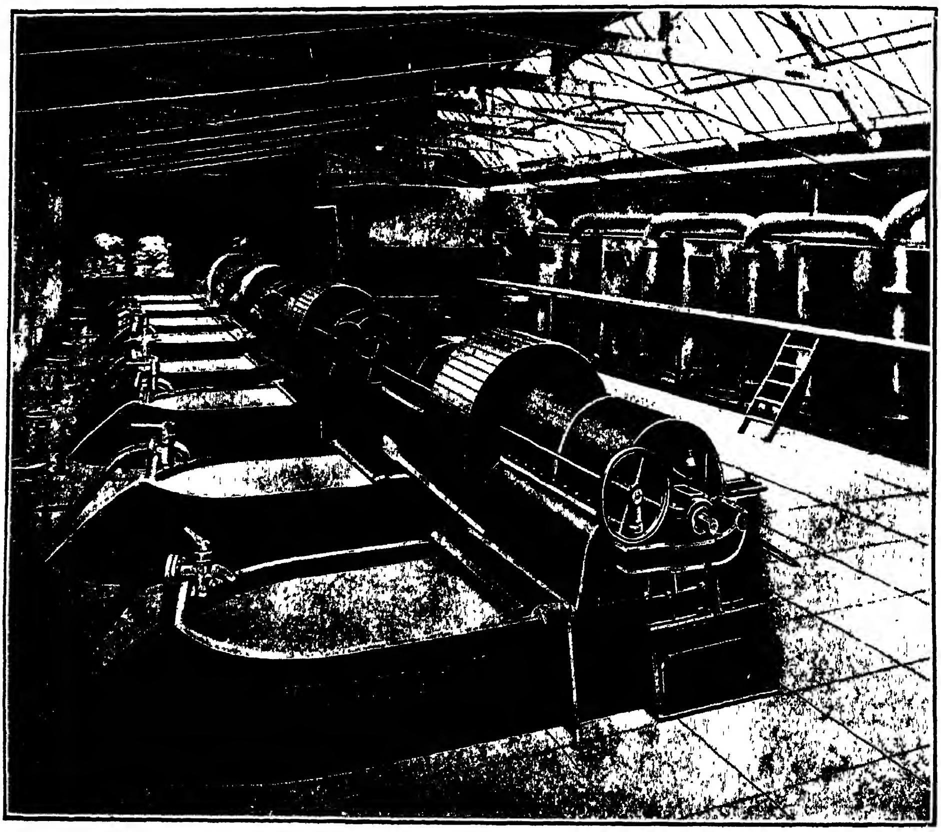
the roll and underneath it, and then up and back again, instead of round the trough. The midfeather is placed under the bed-plate and the roll is well out of the stuff.

We are of opinion that there is little to choose between a well-designed hollander and an Umpherston, but the latter has three distinct advantages—namely, its saving of space, its easier and quicker emptying facilities, and its freedom from 'lodgers'; it is also much more shut in—*i.e.* the stuff is not nearly so exposed to the dust and dirt which are continually falling about in a beater room, as is the case with the hollander. Owing to its being so much enclosed, when beating hard fibres, the stock heats up very quickly.

The Umpherston is a compact, well-designed and thoroughly efficient beater.

The Taylor beater (Fig. 23) is used principally in mills whose furnishes contain a large proportion of esparto.

In beating such stock as esparto and wood it is possible to dispense with those factors which are an absolute necessity for beating strong rag stock. The ultimate fibres of wood and esparto are short, and if the papers made from them do not require to be very strong, their treatment in the beater is sharp



[*Masson, Scott and Co. Ltd.*

FIG. 23.—A BATTERY OF TAYLOR BEATERS, WITH A RANGE OF BLEACHING TOWERS IN THE BACKGROUND

and quick, and must be as uniform as possible in order to produce a very close and evenly made sheet.

The Taylor beater fulfils these requirements admirably, and is being successfully operated in many mills making esparto papers. The beater is entirely different in construction and design from both the hollander and Umpherston types, as will be seen from the illustration.

The stuff is fed into the vat and drops down to the bottom of the enclosed trough, where it is collected by a centrifugal pump, and forced up again through a pipe, to be discharged in front of the roll.

This method of circulation relieves the roll of the necessity of performing

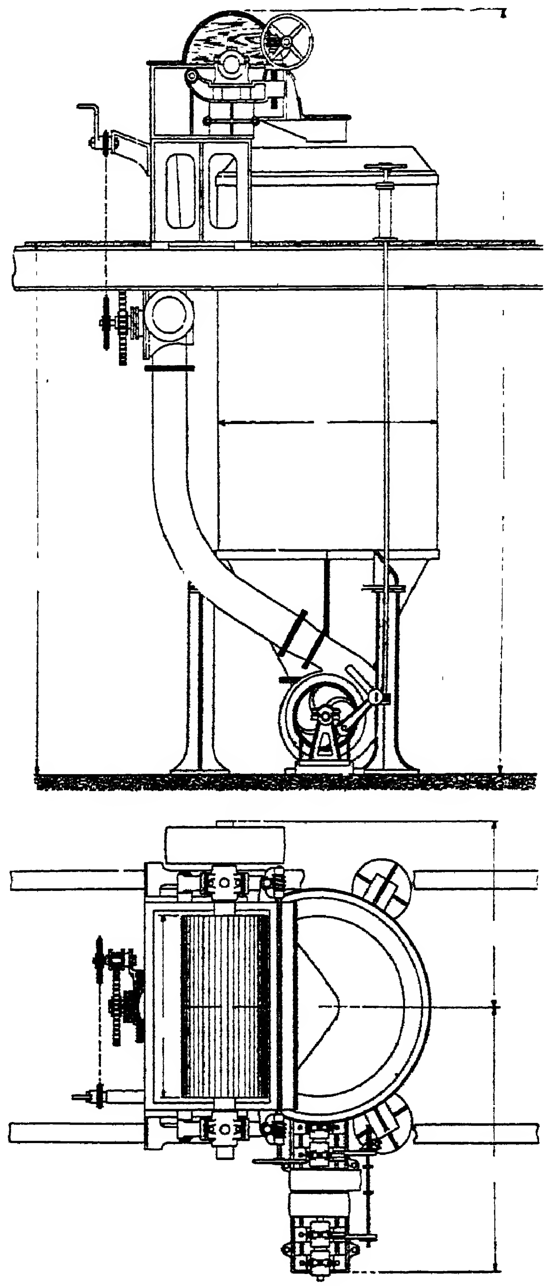
the whole of the circulating or propelling of the stuff, and therefore the roll may contain many more bars, and these may be closely and evenly spaced. It will be evident that this process ensures quick and uniform beating of the stock and saves a large amount of time. The roll is also much smaller and lighter than is necessary with the hollander.

This type of beater is not suitable for the treatment of long-fibred stock, such as rags, as the circulator will not deal with such material, and in any case the treatment of rags with such an arrangement of beater roll would not be satisfactory.

The Taylor beater does not necessarily depend on gravity for discharging the stuff to the chests, as, by the arrangement of cocks and emptying pipe, the stuff can be pumped by the circulator to the machine chests, so that the beater may be on the same floor level as the machine, if necessary.

Very little floor space is required for this beater, and, being enclosed, the stuff is not exposed to dust and dirt from the beater room. The roll and plate are fixed to the floor of the beater room, independently of the pan, in a square casing.

Another beater of a slightly modified design, but working on the same principle, is the Tower beater (Fig. 24), made by Masson, Scott and Co. Ltd. It differs from the Taylor beater in that it occupies less floor space in the beater room, and, being supported usually from the ground floor, the beater room floor can be of much lighter construction.



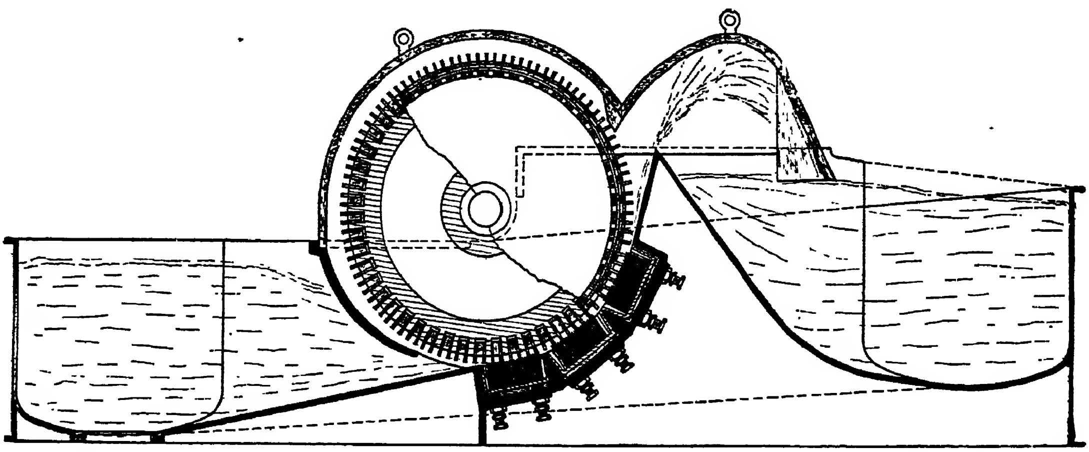
[*Masson, Scott and Co. Ltd.*

FIG. 24.—ELEVATION AND PLAN OF THE TOWER BEATER

The stuff is discharged from the roll down on to a conical hood fixed at the top and inside the tower. This spreads out the pulp and mixes it continuously during the whole of the beating. The bottom of the tower tapers down to a bend, at the end of which is fixed the circulating pump, which throws the stuff up a pipe and discharges it again in front of the roll.

The beating is performed in the same way as in the Taylor beater, and the same remarks apply as to the roll and emptying of the stuff.

The pump circulator of the Taylor and Tower beaters is a great help with short-fibred furnishes such as esparto, since it materially helps 'wetting', and in fact the roll can be lifted quite clear and the circulation by the pump will induce quite a large degree of wetness. Furthermore, the beaters may



[*Messrs. Bertrams Ltd.*

FIG. 25.—SCIENNES HOLLANDER BEATER, SHOWING THREE BED-PLATES PLACED UP THE BACKFALL, ALSO EQUALLY SPACED BARS ON ROLL, AND VERY HIGH BACKFALL

The path of travel of the stuff is clearly shown, also the unusual shape of the wooden cover. Note the baffle plate in front of the roll, to prevent the roll from splashing in the stuff before it reaches the plate

be filled with stuff of comparatively high consistency, and this is a great help in beating esparto furnishes to a given length and wetness. Unless a Tower beater is filled to a point below the conical hood 'lodgers' will collect above and cause trouble.

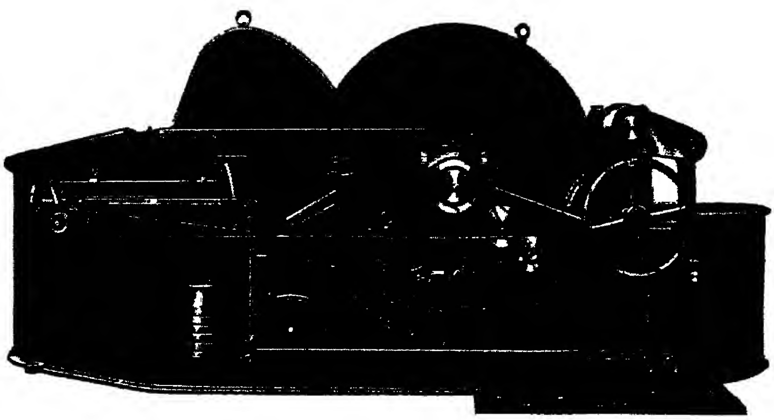
The Sciennes patent beating engine, evolved after careful thought and trial by Samuel Milne, is a great advance in beater design, and is giving good results on a wide variety of furnishes. Of the hollander type, it has several modifications of the usual standard models, and some innovations (see Figs. 25 and 26).

The trough itself is extremely well designed, in order to promote rapid and even circulation, and it is not the usual '2 semicircles joined by 2 sides', in which a great deal of stuff either lodges permanently until moved on by the

potching stick, or only moves very slowly. The shape of the trough is shown in Fig. 16, and paper-makers will see at once that the 'dead spots' in their beaters, which they have often had to fill up with cement or concrete, have been entirely eliminated.

The height of the trough is arranged to coincide with the general height of stuff as it travels round the beater, and it is low in front of the roll and high behind the backfall.

The roll itself is very heavy (9 to 10 tons in a 1000-lb. beater), and the roll bars are equally spaced and not set in clumps. The reason for the heavy roll is to give pressure on the bed-plate, and to prevent jumping and vibration when lumps of stuff pass through, while the fine adjustment provided for lowering the roll prevents all risk of the roll being too suddenly or heavily let down on to the bed-plate. A heavy roll is better for beating strong stuff,



[*Bertrams Ltd.*

FIG. 26.—SCIENNES PATENT BEATING ENGINE, SHOWING AUTOMATIC CONTROL GEAR

which has to be well fibrillated, than a light roll, for it is steady and can be kept at the correct distance from the bed-plate all the time.

As it is impossible for a beaterman, who has a battery of beaters to supervise, to operate them all in exactly the same way each time, an automatic operating gear has been fitted.

The front main lever is operated by compound levers, and the weight is adjusted by hand wheel and screw, so that any desired pressure may be applied. The pressure may be maintained constant from start to finish if need be, but can be easily adjusted to suit requirements.

The bars, as mentioned above, are equally spaced, and not clumped, as has been the usual practice for many years. The reason for this is obvious, for, as every beaterman knows, the first bar of the clump carried most of the stuff and the following bars not enough. Well-separated single bars, especially for long stuff, are the best.

Eighty-eight bars are fitted in this beater roll, which is 60 inches in diameter, and this gives about 2-inch pitch. As a general rule, a bar with a wide edge would be most suitable for beating strong stock which had to be well fibrillated, and a narrower bar for short, free stuff. The wider the bar the greater will be the pressure and crushing action exerted upon the fibres, but a thick bar can be made to cut up stuff quickly enough, provided it is lowered down quickly and kept hard on for a short time.

The bed-plate is very wide, almost one-quarter of the circumference of the roll (in fact, there are two or three bed-plates placed close together), and this, together with the weight of the roll and the well-designed trough, is responsible for the efficiency and great economy of power achieved with the beater.

The chief reason for making the bed-plate so wide is that it is now realised that a large amount of the power consumed by a beater is used in circulating the stuff. In other words, it is wasted so far as actual beating is concerned.

As the beating is done only during the quick passage of the stuff between the bars of the bed-plate and the roll, the way to increase the amount of beating done in a given time is to increase the size of the beating area—*i.e.* the total area of bars in the bed-plate and the area of bars in the roll.

The position of the bed-plate is also different, in that it starts almost exactly under the centre of the roll and takes the place of the usual backfall up to a point. The short backfall takes up an angle of 15°, and is arranged to ensure the pulp being thrown out at the proper place. It will be readily understood that, with this design, the stuff is thrown clear immediately it leaves the last bar of the bed-plate, and there is no heavy pocket of stuff lying between the backfall and the roll, impeding the passage of the stuff back into the trough.

With the usual type of bed-plate and backfall, stuff is flowing into the spaces between the bars all the way up the backfall, and being thrown out again by centrifugal force. This not only impedes the forward flow, but also adds to the power required to drive the roll, and instead of the stuff being quickly got rid of once it has received its treatment, as in the present beater, it is slowly pushed up in rolls to fall over the top of the backfall and into the trough.

In order to obviate the objectionable splashing of the roll in a deep pond of stuff immediately in front of the bed-plate, a baffle board may be carried right down to within about 12 inches of the bed-plate, and the floor of the trough is shaped up to the bed-plate, so that the stuff is forced through this narrow space in sufficient quantity to allow of a fibrage being taken on by each bar of the roll. A smaller opening than 12 inches would be sufficient, but lumps of stuff would be liable to choke it when furnishing.

Modern beaters are designed to circulate in the quickest possible time, and at the same time to possess a large bed-plate area in order that a greater amount of work may be done during one circulation of the stuff. This is done by having a very wide bed-plate, or more often by having a series of bed-plates. There is also a tendency at the present time to use lighter rolls, as it is claimed, apparently with some authority, that the work can be just as well done with lighter rolls and less power.

Beating

Among all the various processes which are used in the manufacture of paper, none has aroused so much controversy and discussion as beating.

'What takes place in the beater?' is still a question that has not yet been answered to the satisfaction of the chemist, the engineer, and last, but not least, the paper-maker.

We propose, however, as paper-makers, to offer an explanation as the result of our experience, aided by the results of the investigations of those who have of late years devoted so much time and careful thought to the subject.

At the outset we propose to divide the subject into two phases, 'free' beating and 'wet' beating.

By 'free' beating we define those processes where such fibres as mechanical wood, esparto, straw, etc.—very short and poor in themselves—require no more than to be separated from clumps or clusters, and are sent in almost, if not quite, their original forms to the stuff chest.

The term 'free' we regard as denoting the result of this elementary 'beating.' The fibres, when passing over the wet end of the machine, part from the water, in which they float, easily and freely.

The power required for treatment can be calculated, and special engines, such as the refining engine, can be used to achieve successful and satisfactory results.

The action of these special engines is not, in the true sense of the word, 'beating', although there is no doubt that some actual beating can, and does, take place when the fibre is of such a form and structure as can stand it. This class of beating suffices for newsprint and other printing papers, and also for all those papers made from esparto with a *small* percentage of chemical wood. It is when we come to deal with papers of a better class, such as writings, banks, ledgers, cartridges, tissues, and 'Manillas', and, in fact, most papers that require to be water-marked, or to have strength, transparency, or any other special feature, that the second phase of beating becomes of paramount importance. Then, in various degrees, the stuff must be what has been called by the older paper-makers 'beaten wet'. We by no means dismiss the first class of beating

—namely, what we call 'free'—as of no account or unworthy of investigation, but will confine ourselves to the second class, as being what is admitted by all concerned to be the representative process for all 'beating'.

When the first prehistoric member of the Paper-makers' Association started to make paper he found that one part of the process entailed a great deal of heavy work, and no doubt delegated the pounding or beating of the fibres to his sturdiest employé. Up to the present day, to produce a strong paper from 'rags'—we will assume this to be a representative of the whole class—the

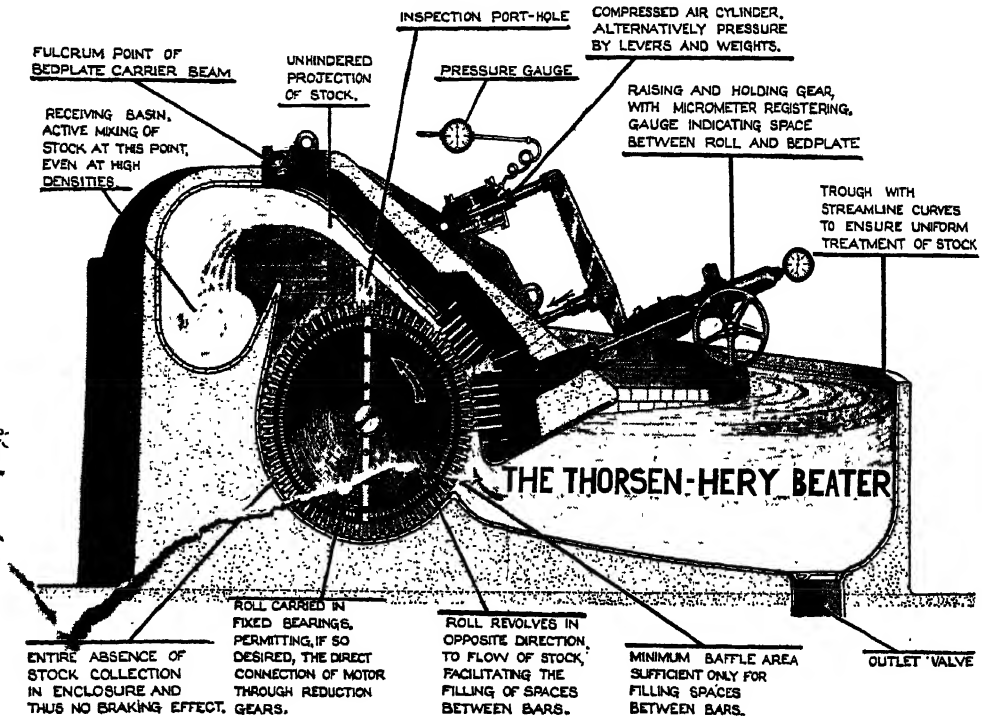


FIG. 27. [*Bentley and Jackson*

greatest power is consumed by the beating process. To reduce this great consumption of power, to 'beat' the rags to produce what we require, with the minimum expense for fuel, is the ultimate object of all investigators of the process.

Before we can do this, we must find out what takes place in the beater. We can do this only by examining results, and formulating a theory which will agree with these results. Now it is agreed that if two beaters furnished with identical quality of stuff are run off at the machine, and one is beaten 'wet' and the other 'free', the one that is called 'wet beaten' invariably produces the strongest paper. This brings us at once to the point where we must define what we mean by 'wet beaten' stuff. In a word, it is stuff which parts with its water very slowly. It will go from the breast to the suction boxes without losing much of the water in which it is suspended.

When passing over the suction boxes a high vacuum is required to withdraw sufficient water to allow the web to be couched without being crushed. This is what a machineman will understand by 'wet' stuff, and for practical purposes the word will express the idea to most paper-mill men. However, for more scientific men the word did not correctly define the condition, and they renamed it 'hydrated' stuff, a word which really means 'combined with water' in a chemical sense.

The question then arose as to whether this so-called combination of stuff and water is caused by the mechanical action of the beating engine or by some obscure chemical process.

The theory of 'fibrage' pronounced by Dr. Sigurd Smith was hailed as a great discovery by the paper-making world. Without in any way wishing to detract from the value of this investigator's patient labours, we are of the opinion that he leaves us, for any real explanation of the subject, just where we were before. He has not shown us how to beat stuff 'wet', or *hydrated*, by using less power.

He does indeed indicate how power and time may be saved by using two plates, and causing one circulation of the stuff in the engine to give results hitherto obtained by two circulations, but the fact remains that the actual power that is necessary to 'beat' remains the same. He gives us no explanation of beating which will enable us to get 'wet' or 'hydrated' stuff by any other means than the beating engine.

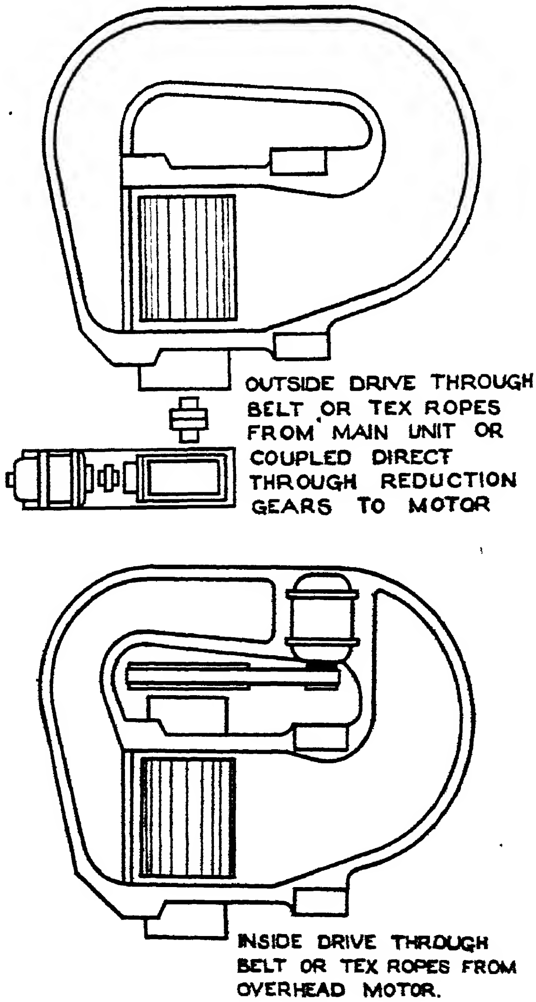


FIG. 28.—PLAN OF THORSEN-HERY BEATER

As for the 'chemical' or 'physical' question, we should think that, after the published results of the researches by James Strachan, no one will seriously claim that chemical combination of stuff and water can take place, except in an extremely limited degree.

This being so, we venture to assert that the term 'hydrated' stuff is

misleading and erroneous. It has been presumed that stuff must be wet or hydrated before it is in that condition which makes the strongest paper.

Mr. Strachan, in our opinion, conclusively proves that 'hydration' is merely the *sign that the stuff has attained that condition*, and our personal experience in beating entirely coincides with his proof. He shows that when the fibres are subdivided into *fibrillæ* and partly crushed into very fine particles, more water adheres to their surfaces, or that the mixture of stuff and water has become more intimate; each minute particle of stuff has its *superficial area increased by subdivision*, and that additional surface area is covered by a film of water. Therefore, the fact that extra water has been attracted to the stuff is not the reason why the paper will be stronger, for the strength is caused by the fibres being '*fibrillated*', and this, we think, is the proper word to describe the condition.

It can certainly never be asserted that water adds strength to fibres; therefore it must be that they gain strength by being *fibrillated*.

Now let us describe what does actually take place in the beater from this standpoint. We will presume that we have got a hollander furnished with linen fibres. This stuff has been boiled and gas-bleached to remove all shive.

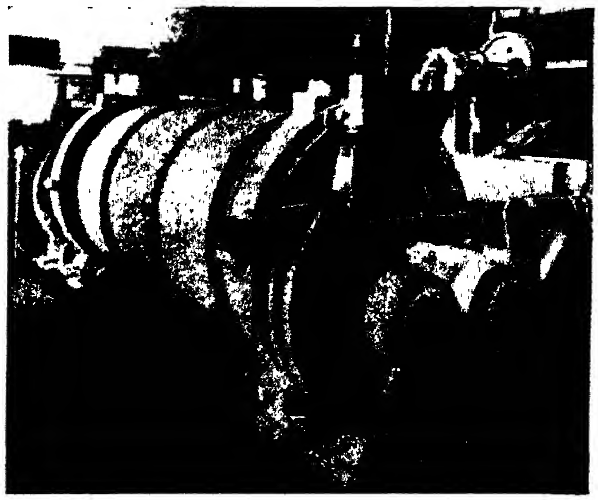
We may presume that in these processes the fibres have been thoroughly saturated with water. Indeed, it is inconceivable that thorough saturation has not taken place. Every pore, canal and surface of each individual fibre has its full quota of water; yet it cannot be said to be *hydrated* in the true meaning of the word.

To return to the beater. We know that if we simply clear the fibres of knots, etc., and run them over the wire, the sheet will look raw and cloudy, and the fibres will be too cumbrous to felt with each other, and may be easily pulled apart. The dandy roll will be unable to make a proper impression on the sheet. Therefore we have to '*beat*' the linen fibres—and 'linen takes a lot of hammering', as every beaterman knows—in other words, we must have the fibres well *fibrillated*. If our beater bars are too sharp we have great difficulty in fibrillating the fibres; instead, we may cut them and have free stuff, which is not at all what we set out to obtain. But if our tackle is dull—*i.e.* the plate is well worn and the bars are blunt—we can put our roll down on the plate. Then, whether through fibrage on the bars, or the stuff being drawn through by the vacuum of the beater-roll spaces, the process of 'fibrillation' commences. As every beater bar passes the plate, so many fibres will be struck and bruised between the flattened surfaces of the bars and plate.

If a fibre is struck longitudinally, it may be divided into several fibrillæ; if across, it may still be fibrillated where the blow falls, thus exposing more surfaces to the water in the beater. But it is bound to be the case that many fibres

will be so heavily struck that they will be partly fibrillated and partly bruised; the bruised portion will give up some of its particles to float in the general mass, other particles remaining attached to the fibrillæ. If the beater is run long enough, all the fibrillæ will in time be crushed into these fine particles and become quite useless for paper-making. Therefore, our object is to stop the action when we have most fibrillæ and a good proportion of these particles amongst them. Our engine of stuff will be fully fibrillated. These fibrillæ and many fibres partly flattened, and some cut through with fibrillated ends, are obviously what will interlace to make a tenacious sheet, and the finer particles will settle into the minutest spaces between the larger fibres and still further entwine them together.

By this latter action we lose bulk but gain strength, solidity—shown by hardness of rattle—and transparency. Now in the making of our fibrillated stock into paper our greatest difficulty lies in getting rid of the extra water carried by the stuff. Some is drained out by the sucking action of the tube rolls of the wire, some is drawn out by the suction boxes and suction couch. The pressure of the press and couch rolls accounts for a great deal. But all the extra surfaces of the fibrillated fibres retain some surface water, and part with it only by evaporation on the hot drying cylinders.



[*Bentley and Jackson*

FIG. 29.—THE NEYTHOR PRESS

It simply amounts to this: we have to dry a much greater surface area when the stock is highly fibrillated than when the stuff is free beaten.

Again, it is a matter of great difficulty to run heavy substances, say 72 lb. Imperial, when using a rag stock highly fibrillated, to produce a strong paper. The maximum strength obtainable from the stock is limited to the capacity of the machine to extract this unwanted water on the wire before the couch nip—*i.e.* the stuff must, in most cases, be let down to the chest before it has been beaten long enough to get all the good out of its fibrillating capacity. To overcome this difficulty it is common mill practice to use steam heat in the stuff and water. This is said to 'dehydrate' the stuff, but this dehydration does *not* reduce the strength of the paper. The increase of temperature reduces very greatly the viscosity of water, and it is this viscosity of water

which is the cause of the trouble at the machine when making thick papers from highly fibrillated stock.

The finished sheet has its strength from the 'fibrillated' condition of its mass, which is the essential factor, and *not* from the water which has clung to the fibrillæ, and, being only incidental to the condition, has been removed.

This explanation of what happens in the beater is supported by paper-making practice and common sense, and it seems to us that in no way, except by the exercise of power, can we achieve this particular condition of stock.

Attempts have been made to reduce the time and power required for the fibrillation of the stock by producing a formation of mucilage or slime by means of acids or alkalis.

No success seems to have attended these experiments, which were, indeed, doomed to failure, because they were based on a false hypothesis—namely, that wet, greasy or slimy stock must be productive of a strong paper.

A moment's thought would have shown that the reduction of a fibrous material to a starchy paste could not increase its strength. The condition aimed at in these experiments does, however, come nearer to that to which the true meaning of the word 'hydrated' may be applied. But it is of interest to note that the wetness obtained gave no additional strength or quality to the paper, or, at the most, only what would have been achieved in greater degree by mixing a quantity of good starch with the fibres in the beater.

There are, however, well-known methods of improving the strength and hardness of paper by adding adhesive substances to the pulp in the beater. These substances simply glue the fibres together at the presses and drying cylinders of the machine. None of these in general use at present, however, will give the increase in strength which may be obtained by skilful fibrillation.

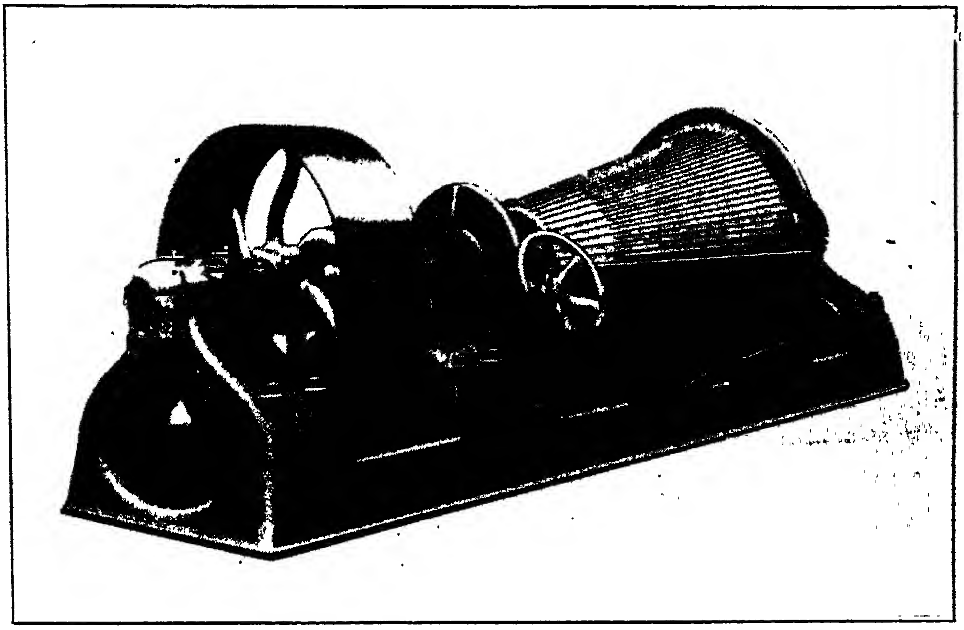
We think that, instead of trying to fit mysterious explanations to what is, after all, a very simple mechanical process, chemists should turn their attention to the discovery and application of some substance, or chemical compound, which, when mixed with ordinary cheap paper-making material, will give a paper with strength and qualities equal to those of a well-fibrillated sheet made from cotton and linen fibres.

Fibrillation, with its great consumption of power, would then give place to the cheaper method we call 'free' beating, and our object would be attained.

Refining

After stock has been beaten in the hollander or other beater of the same type, and before it can be let down to the machine chests, it is necessary to set the roll so as to 'clear' the fibres. This clearing consists in breaking or brushing out

fibre clusters or particles of pulp or paper that have in some way escaped the action of the roll and plate, or have been packed into knots or lumps by the violence of the beating. The roll is raised so as to be just clear of the plate, and the beaterman uses the stirring-stick freely to turn up the stuff in those portions of the trough that experience has shown to have a sluggish circulation. The clearing proceeds until a sample of stuff examined in a hand-bowl shows no lumps or knots or paper 'bits'. This may take from 15 minutes to 1 hour, according to the fibres or stock being treated and how it was prepared previous



[*Masson, Scott and Co. Ltd.*

FIG. 30.—MASCOT REFINER WITH TOP HALF OF CASING REMOVED, SHOWING CONE

to beating. Broke filled into the beater without preliminary treatment is very difficult to clear; in fact, sooner or later uncleared bits, notwithstanding every precaution, will get to the machine chests and spoil the paper.

A lump of pulp or paper may lodge about the plate or backfall or stick about the bottom of the beater, and be flushed down to the chests when the beater is emptied. This danger, and the time and power required for clearing, brought the 'refiner' into being.

The refiner (Figs. 30 and 31) is a machine expressly designed for clearing beaten stock, and its proper working position is exactly the same as the beater roll 'clearing'.

When the beating proper has proceeded far enough, the action is stopped and the refiner takes up the work. Instead of the whole charge circulating round the beater, for the purpose of treating what is relatively a very small

amount of stock, and consuming time and power, the charge is let down to the refiner chest, the stuff is immediately started on its way to the machine, and the beater is refilled.

The refiner usually consists of a cone-shaped shell or case (Fig. 30) on the inside of which are set, longitudinally, bars similar to those in a beater plate, with knees or zigzag formation. An internal conical rotor fitted with straight bars is mounted on a shaft so arranged that the bars may be brought into close contact with the bars on the inside of the outer shell. In some refiners there is also a disc with corresponding blades on the rotor disc. The central rotor is

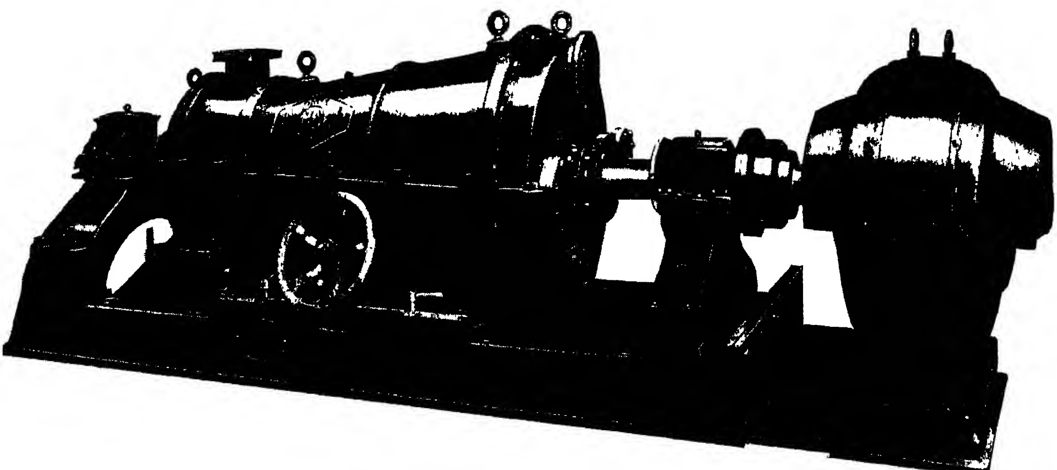


FIG. 31.—THE MASCOT REFINER [*Masson, Scott and Co. Ltd.*

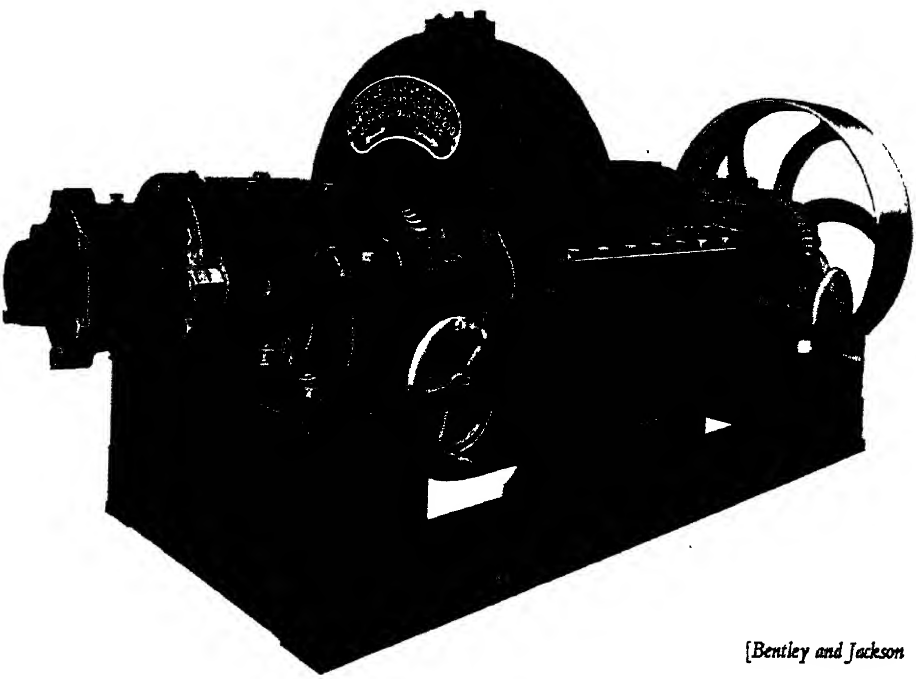
adjustable by a hand-wheel and traversing gear, which moves the shaft and cone into the outer cone, bringing all the bars on the rotor and disc into contact. The illustrations clearly show the arrangement of bars.

When properly set, stock that is clear passes readily through the machine without being cut or injured; larger or uncleared fibres, knots of stuff, etc., are caught by the bars and rubbed out or cut before they can pass through.

The stuff enters at the small end of the cone, and is discharged from a pipe on the circumference of the disc. It is obvious that the action can be made more drastic, though at a very great expenditure of power. The rotor may be pressed harder against the outer cone, when the refiner takes on the action of a beater with extreme cutting characteristics, especially as the stuff is at a much lower consistency than in the beater. To overcome this difficulty concentrators are sometimes used to extract water from the stock before it enters the refiner. After passing through the refiner in a highly concentrated condition, the stock and the extracted water are again mixed together. Under these conditions there is no doubt that fibrillation takes place with some fibres,

notably those that are soft and well boiled. The fibres that are most successfully treated by refiners are, however, those that we have already mentioned as requiring 'free beating'—*i.e.* mechanical pulp, esparto, etc. The fibres from broke and waste paper, which have been already treated for paper-making, and require only to be defibred, form another class which can be 'beaten' by the refiner, provided always that they are well saturated with water in the beater or breaker.

The use of the refiner has been extended in many mills using the above classes of stock, to cover nearly the whole of the beating, the beaters or breakers



[*Bentley and Jackson*

FIG. 32.—THE MARSHALL REFINER, DISC END

This refiner has a disc as well as a cone, and the disc is chiefly used for clearing the stuff and freeing it from knots

themselves being used for little more than the preliminary mixing of the stuff, alum, size, dye, etc.

The wisdom of this method is open to question, because the refiner is worked hard up, and fibres that ought to be brushed out and fibrillated (the proportion of chemical wood in newsprint, for example) are cut fine to give a close sheet, and so their full value is not obtained.

The refiner being a modified type of beating engine, it is, of course, possible to beat certain papers by means of a series of refiners, the stock being passed from one engine to another. A strong 'bond' paper may be produced from chemical wood pulp in this way, especially successful being those mills which can get their pulp straight from the digester. It is difficult to see what is gained

by this method; a series of, say, Tower beaters would probably be more efficient and use less power.

The refiner is a very excellent machine for certain purposes, if used with extreme care and intelligence, but it produces disastrous results if carelessly handled.

It is now the practice in some mills for the refiner to be placed in the machine house and under the control of the machineman. The reason for this is that it is becoming recognised that it is possible, by the use of refiners, to alter slightly the appearance of the sheet and also assist the machineman in closing up his sheet when necessary. Previously the use of a refiner was to clear the stuff after it had been taken from the beaters into a refiner chest; the stuff then passed from the refiner into a machine service chest. The new practice calls for a different arrangement, which is as follows:

The refiner is placed after the stuff pump and immediately before the head box; the stuff is left slightly longer by the beaterman than would be the case if there were no refiner. The machineman on starting up examines the sheet and then sets his refiner to reduce the length of fibre if necessary, and to clear the stuff of knots. The beaterman is thus relieved of the necessity of clearing his engine, sometimes a long and difficult business with certain furnishes, and a lot of power is saved in the beater room. It was quite a common thing, especially in rag mills, for a knotty engine to be let down, and thus spoil a whole chestful of stuff. There was no alternative other than to run the stuff out as broke. With the refiner arranged as part of the machineman's equipment this is not so likely to happen, as the stuff from the knotty engine can usually be cleared in a minute or two. Further, the placing of a refiner in this position, where it deals with the stuff immediately before it passes on to the machine, gives a far better separation of fibres, and enables a much more close and even sheet to be made.

We are of the opinion that the time is not far distant when this method will be universally adopted for many classes of papers. The Marshall type of refiner (Fig. 32) seems to be peculiarly well adapted for use in this position, as it has the additional advantage of the disc as well as the cone.

BEATING OF VARIOUS FIBRES AND THE CHARACTERISTICS THEY IMPART TO PAPER

COTTON—LINEN—WOOD PULP—ESPARTO—STRAW

Cotton.—Cotton may be used to produce a great variety of papers. In practice the use of new cotton fibres is limited to the making of high-class papers, on account of the high cost of the raw material, and the power and labour consumed in beating, making, tub-sizing and finishing. This fibre is supreme for very strong loan, ledger paper, thin banks and the best qualities of writing and drawing papers.

The most durable, though perhaps not the most absorbent, blottings are made from new cottons. The degree of fibrillation given to these papers varies to extreme limits. Thus, for a strong loan of the substance of Large Post 21 lb., from 6 to 8 hours' beating may be required, while a very close and clearly water-marked writing paper of the same substance and quality will take from 2 to 4 hours.

Since in most 'fine' mills both of these papers will have to be produced by the same beating engines, it is a matter of the highest skill to manipulate the rolls to fibrillate the loan properly if the tackle is moderately sharp. On the other hand, the cutting rather than fibrillating of the fibres, for the writing paper, would be much easier to accomplish. If the tackle is dull and blunt, the difficulty would be to get the fibres for the writing paper cut fine enough without too much fibrillation taking place. Again, the plates and bars wear down and become dull as time goes on, and this renders all records of roll pressure useless, since the conditions are constantly changing. Thus we are left, in the long run, dependent on the skill of the beaterman who knows the conditions and beats according to his judgment. Therefore, though statements of beating time might conceivably be given for different weights and qualities of paper, they would be correct only in a very general sense, and only in that sense can they be given. For instance, if the paper we are considering (a strong loan) were being dealt with by four beaters, of which one had a fresh and consequently sharp plate, the beaterman could not by any possible manipulation of that beater give the stuff in it the same fibrillation as

in the others in the same time. It is doubtful whether by having less pressure on the plate and giving the stock longer time he could ever accomplish it.

Besides the condition of the tackle and the beating pressure, the concentration of the stuff makes a very great difference to the result. The strong loan and the fine writing paper may again be instanced. In a beater nominally of 400 lb. capacity, the quantity of the former may be as much as 4 cwt., and of the latter not more than 3 cwt. The writing paper will not have the strength of the loan, but this is not expected, or required, the main consideration being a close and clearly water-marked sheet. The lower the concentration of stuff in the beater the more chance it has of being cut, owing to the fibres passing through between the bars and plates in a thin stream, instead of a thick layer. An exactly similar effect is seen when finishing a thin paper on the calenders. When putting through a thicker substance with the same weight of rolls, the finish is not so high. The thinner paper has fewer fibres in its bulk to form a cushion, and therefore each individual fibre has the weight more directly applied to it.

Again, by the higher concentration of stuff, the fibres are subjected to more pressure and rubbing on each other and against the sides and bottom of the beater, which helps to roughen the surface of the fibres and separate the fibrillæ that have been opened up by the roll. Also, the head of stuff in front of the roll is subjected to a battering effect by the roll bars, which is absent when the stuff is rushing through, suspended in water. Between the plate and the outlet of the backfall, a good deal of pressure and rubbing takes place.

Although we have taken cotton fibres as an example, these remarks are applicable to all kinds of fibres. Cotton fibres, especially those from new cotton cuttings or rags that have not been subjected to frequent washing and bleaching, are very opaque and bulky. Even when well fibrillated, as in a thin bank, this is apparent. As we have shown previously, the cotton fibre has a peculiarity which is of the highest value in giving the qualities of strength, bulk and opacity. This is its twisted form, which even after drastic treatment in the beater is seldom entirely lost. As an illustration of these qualities combined, let us take a ledger paper of a substance equal to about 27 lb. Large Post, with a water-mark. The beating time would be about 4 to 5 hours, and our beater would be filled to about 3½ cwt. of stuff. We would then expect to find that the stuff would be rather wet on the machine, but the fibres would be fairly long, or at least a good proportion of them. If some of these long fibres are examined under the microscope most of them would be readily recognised as cotton by their more or less twisted form. These are the fibres that have escaped being much cut or fibrillated during their time in the beater, and they form the backbone or framework of the sheet. While

they are firmly bound together by the fibrillæ, they serve to prevent the close packing of a more highly fibrillated paper. At the same time the wetness or fibrillation of the other fibres allows the dandy roll to make a good impression. Thus we have the natural strength, bulk and opacity of the long fibres, and the felting strength and clear water-mark given by the fibrillæ.

While we have this illustration before us, we may just touch on a point in beating which seems to have been overlooked by many so-called beating experts, who seem to consider that the perfection of beating is to have the fibres of a uniform length. This is true only so far as the beating for printing, litho and such-like papers is concerned. But the ideal ledger paper, and indeed many other papers, cannot be properly made by fibres beaten to a uniform length. This is one of the factors that have kept the hollander beater in the highest place as an efficient beating engine. Its irregular and unequal circulation, even in the best designs, ensures that many fibres are little touched, while others may be driven through the nip many times.

Unless there were a fair proportion of long fibres to form the framework of the sheet, there would not be much strength and bulk, and without the fine fibrillæ there would be poor water-marking and felting.

Reverting, however, to our writing-paper example, uniform length of stuff is of more advantage, because strength may be considered of secondary importance. The fibres being *cut* to produce fine stuff still retain their original characteristics, opacity and bulk. The quicker circulation of the less concentrated and lighter-charged beater will ensure that fewer fibres escape being cut. Cotton beaten quickly—*i.e.* cut fine—carries the water well up to the dandy roll owing to the close packing of the fibres. The roll makes a good impression because there are fewer long fibres to prevent the sinking in of the protruding letters or designs. After passing the dandy roll, however, the suction boxes are seen to take the water out of the sheet very easily, showing that little fibrillation has taken place in the beater.

If, however, we intend to make our writing paper of thinner substance, say 18 lb. Large Post, we have to alter our beating a little. We must fill in more stock and allow a little more time to beat, so that we may have some long fibres and more fibrillæ, to help to run the paper over the machine, without having breaks and 'pick ups' at the dandy roll. We can do this because the thinner substance allows and requires more water to be used on the machine to close up the sheet, and the impressions of the dandy roll are more transparent. From this a step further, higher concentration of stuff and still longer time beating, give us stock suitable for a bank paper of 15 lb. Large Post, and so on down to thin banks of 11 lb. and under.

Reversing the process, as we increase the substance of our paper to, say,

a ledger paper of 72 lb. Imperial, we have to beat with less fibrillation. This is not because we do not require strength, but because we find it very difficult to get the water out of the fibrillated stuff when we run it over the wire. Therefore the beating is required to be a very skilful compromise between cutting and fibrillating the fibres. We must not cut them too short or strength will be badly down; we cannot leave them long and raw or we will have trouble in getting them through the strainer plates and get a poor water-mark. In general, with a fair quality of cotton fibres, if we treat them as for a ledger paper of about 30 lb. in Large Post, by heating the stuff to about 90° to 95° F. on the machine, a successful result will be achieved.

With substances heavier than this, strength has to be proportionally sacrificed to the capacity of the machine to extract water, and the fineness of the strainer slits. A good cotton furnish beaten for 1 hour with sharp plates may be run up to 150 lb. Imperial on a 40-foot wire of 66 mesh at 15 to 20 feet per minute without heating at the machine. Heating up to 90° to 100° F. allows the stuff to be put down with a little more length, as more water can be used to run it through the strainers.

When dealing with cotton fibres from old rags, more gentle treatment is necessary. Fibres that have been subjected to prolonged wear and repeated washing and bleaching before coming to the mill, and then to a fairly drastic treatment there, have lost a great deal of their stability and bulk, and—worse still—have become partly oxidised. Fewer twisted fibres are seen, and the most careful beating cannot make up for the loss of their original strength. They are also frayed and bruised (*i.e.* fibrillated), and therefore work wetter on the machine. They serve to make rag papers that may be sold comparatively cheaply and fulfil a more modest standard of quality, and they form the basis of the great majority of writing and ledger papers.

Old soft rags, suitably treated and beaten with very sharp roll bars and plates, make the softest and most absorbent blottings. The beating time is from ½ to 3 hours, according to substance. Blotting Demy ($17\frac{1}{2} \times 22$) varies from 18 to 120 lb.

Owing to its absorbency and the purity of its fibres, cotton takes most dyes very readily and produces very brilliant shades.

Cotton fibres blend extremely well with the fibres of chemical wood, and very beautiful and useful papers of all types, from the thinnest banks to the thickest chromos, may be made from a mixture of the two.

The strongest form of cotton rag is that known as 'new unbleached calico cuttings' from cloth which has been woven from Egyptian cotton. The half stuff from this material bleaches up to a beautiful snowy white and may be beaten to yield very strong papers of all substances.

In general, papers made from cotton fibres are more bulky, and handle better than those made from any other fibre, or mixture of fibres, and it is this quality which renders them very valuable, and in fact indispensable, for papers which are required to bulk well.

Linen.—The value of the linen fibre to the paper-maker lies in its great capacity for fibrillation. Its thick walls are fundamentally striated and its canal is small in comparison with its bulk. Obviously it will require heavy beating to disintegrate it. Unless the bars and plates are very sharp it splits more readily than it cuts. For this reason, compared to cotton, its use is rather limited except for special papers. It is seldom, if ever, run as a whole furnish, but it gives, even in a small proportion, a certain 'feel' to paper which can be readily distinguished by a skilled paper-maker. This feel is very difficult to describe, but may be attributed to the cool, glossy surface of the fibre.

It does not readily take a good water-mark unless highly fibrillated, but in the latter case the binding effect of its fibrillæ gives great strength and hardness. For a good ledger paper, up to 25 per cent may be used with advantage. It must be beaten separately, and not in a beater with the other components of the furnish, as the heavy treatment it requires would destroy the strength of these components to a greater extent than the linen could compensate. Perhaps neglect of this very obvious precaution is the reason why many paper-makers assert that linen has less strength as a paper-making material than cotton.

A blend of chemical wood with 10 per cent of linen gives a paper of surprisingly good strength and hardness, and—judging from the frequency of this combination in many papers we have examined—it is a very popular one.

Although an all-linen paper is very seldom met with, in thin papers the proportion of linen may be greatly increased with excellent results. With about 8 to 12 hours' beating with dull tackle and high concentration of stuff in the beater, a furnish of 75 per cent linen will produce a pulp that will work extremely wet on a 66-mesh wire at 7 lb. in Large Post and give a very strong paper.

The hardness of the linen fibre renders it more immune from serious damage in the beater than is the case with cotton; for while a careless manipulation of the roll during the first hour or two in the beater will ruin a furnish of cotton, the linen seems capable of standing the weight of the roll better, and is not so likely to be spoilt unless all the tackle is very sharp.

There are various reasons for the linen fibre being more easily fibrillated in the beater than cotton. In the first place, as we have already said, the structure of the fibre lends itself to longitudinal splitting, and in addition the fibre contains knots or bulbous swellings which split and become fibrillated by the weight of the roll.

There is, however, another reason which accounts in no small measure for the easy fibrillation; it is, in fact, that the linen cloth, in the case of new cuttings or used rags, has had much more hard usage during its existence prior to its arrival at the mill.

The linen fibre, being itself hard and harsh, produces a correspondingly hard thread and cloth. This cloth is so harsh and lacking in suppleness that it is unsuitable for clothing or household use until it has been softened and made pliable by the linen cloth manufacturer. To effect this softening the cloth is beaten, or 'beetled', as it is called, by wooden beetles, or clubs, so that someone else has a hand in the fibrillation of the stuff before it is put to its various domestic uses. Again, linen being hard wearing, it lasts many years in the form of sheets, tablecloths, etc., and in consequence it is laundered many times more than a similar article of cotton.

All these things help in the preparation of the rags for the beater, so that by the time the linen stock has been broken into half stuff in the beater, it is already well fibrillated and feels wet and greasy to the touch.

The amount of linen which can be used in the furnish is really limited by the length of the machine wire and the efficiency of the suction boxes; for if, with 25 per cent of linen, the paper can just be couched without crushing, it is no use to bring up the proportion of linen to 35 or 40 per cent. This will only give the machinemen endless trouble trying to get the water out, and the appearance of the sheet will be spoilt without any appreciable gain in the ultimate strength of the paper.

In general, if linen is to be used, it will be found advantageous not to use too much, but to get full value from a moderate amount by carefully beating it with blunt tackle, and so defibring it that it will entwine and bind together the rest of the furnish and give that characteristic hardness to the finished sheet.

When the furnish is to be 25 per cent of linen and 75 per cent of other fibres, beaten separately in four engines, it will generally be found best to furnish the linen first and leave the other fibres till last, as it will be the last to reach a satisfactory state of fibrillation, providing that the tackle in all beaters is in the same state.

Never beat a mixed furnish of cotton and linen in the same beater if it can possibly be avoided, for, unless the amount of linen is small, the amount of roll required to beat it will destroy the cotton, and the result will be worse than if no linen had been used.

Wood Pulp.—So far we have been dealing with materials that require heavy beating or cutting. That is to say, a great deal of power is consumed by the beating engine, in the one case for fibrillating and in the other for cutting fibres.

Wood pulp fibres are short enough in themselves to need little cutting, and they have not the structure or stability to produce extensive fibrillation. This brings us to the obvious conclusion that it is possible to find beaters more economical than the hollander for the treatment of wood fibres. Not that any improvement in the quality of the paper made from wood pulp in a hollander can be looked for by using any other type, but because it is uneconomical to have to drive a heavy roll, whose weight is never fully used, and because of the slow and uncertain circulation of the hollander.

The beating of wood fibres is confined in a very great measure to clearing fibre clusters and 'brushing' the fibres so that they are roughened by the partial fibrillation of their surfaces.

This suggests a type of beater with a lighter roll and quicker and more perfect circulation than the hollander. Many good beaters of this lighter type are now in use, such as the Taylor and Tower beaters, which have separate circulators and light rolls, and are found to be perfectly efficient in beating wood, esparto, and straw.

Many qualities of chemical wood pulp show a surprising degree of fibrillation when examined under the microscope, after careful beating, and run well on the machine. They are suitable for the cheaper kinds of typewriting papers, and down to 15 lb. in Large Post will take nice water-marking. Under that substance it is difficult to water-mark an all-wood furnish without a great deal of trouble with dandy 'pick-ups', but very thin papers may be made with a plain wove dandy roll. The reason for the trouble with dandy picks is the shortness of the fibre. Certain qualities of wood pulp are, however, now available which take a good deal of beating and produce long, wet stuff.

Wood pulp produced by the soda or sulphate processes has better bulking qualities than sulphite pulp, but tends to be too free and raw for these papers.

Under the beating of wood pulp comes the important operation of treating newsprint stock and stuff for cheap printings and supercalendered papers. In these cases we have the best examples of 'free beating' as opposed to the beating of cotton and linen for the manufacture of writing papers.

The beating of newsprint is usually divided into two operations; the first consists of soaking and mixing the strong sulphite and mechanical pulps in a large hollander type engine, which has a roll with single and equidistant bars, as opposed to the usual clumps of three or four bars. The sulphite is furnished first and then the moist mechanical and broke, or the broke may be mixed up in a separate engine. The chief requirements are maximum speed in furnishing and the elimination of wire bands and bits of wood from the bale wrappings, as these are liable to do damage later when the stuff is passing through the refiners.

To save time in furnishing the engine all the bales of pulp required should be stacked close round the beater, or on a wooden stage at the edge, and before the previous lot of stuff has been emptied the hoops should be removed and taken away.

As soon as the stuff is let down the white water is turned on and the pulp thrown in—so many bales of sulphite followed by the required amount of mechanical. The proportion is usually in the neighbourhood of 20 per cent sulphite to 80 per cent mechanical.

As soon as the pulp is properly broken up and mixed, say in about 1 hour, the valve is drawn and the stuff let down into the refiner chest. Here it is diluted to a consistency suitable for pumping through the refining engine. It is during its passage through the refiner that the beating (such as it is) and clearing of the stuff are effected, and the beaterman manipulates the disc of the refiner in the same way as the roll of the hollander is manipulated when beating cotton and linen rags.

The consistency of the stuff as it passes through the refiner is important, just as it was in the beater, and the more concentrated the stuff the more 'beating' will it get, and *vice versa.*

It is usual to have two refiners coupled together, the stuff passing through the first and then straight through into the second and into the machine chests.

The chief requirements for the satisfactory production of newsprint stock is absolute uniformity hour by hour and day by day, so that the machine can be kept going at full speed for very long periods without breaks. Consistency regulators should always be fitted, in order to check and maintain the uniformity of the stuff.

Once the machine has started up and got into its stride it is up to the beaterman to keep his stuff absolutely regular and at a uniform degree of 'freeness', so that just sufficient water will be carried to enable the sheet to be put together and no more. Once the web reaches the suction boxes it must part readily with its water so that it may be easily couched.

The beaterman must see that his assistants use care in furnishing so that no pieces of wood or foreign matter get into the beater, as these things, when broken up by the refiner, pass into the web in the form of small splinters and shive, and cause breaks.

Properly beaten with suitable tackle, sulphite wood pulp can be made to produce beautiful banks and bonds; and thin tissues, down to a substance of 5 lb. Double Crown, may also be made, their strength and toughness being comparable with tissues made from rags.

The production of these thin papers necessitates long and careful beating and proper tackle; blunt bronze bars or, better still, stone rolls give the best

results, as the original length of the fibre is preserved and the long-continued brushing out of the fibres gives the necessary fibrillation and subsequent wetness.

Esparto.—Esparto fibres are very fine and short; nevertheless they require a certain amount of beating. This amount depends on the quality of the grass and the treatment it has previously received. The fibres of Spanish grass are tougher than those of African, and will stand more beating, thus giving a stronger and harder paper. In order to eliminate shive, esparto fibres must be well brushed or rubbed, with as little cutting as possible. This must not be carried too far, as they are naturally slimy, and if the process is overdone small knots will form in the chests and strainers and the web will stick to the press rolls of the machine.

Sometimes a charge that has been overboiled or overbleached will defy the efforts of the beaterman to make it into a good running paper, and then the only remedy is to increase the proportion of wood pulp in the furnish. Esparto is not suited for running over the machine without a proportion of chemical wood fibres to form a base or framework for the paper.

As might be expected, esparto papers are very close and regular in composition and take a very clear water-mark. They take a very fine finish with light calendering, and give a more bulky paper than wood pulp with the same finish. For this reason they are most suitable for fine printing papers.

Esparto is very absorbent and requires a great deal of resin size to make a hard-sized sheet. It produces an excellent tub-sized paper with a good hard rattle and more strength than might be expected. The uniform size of its fibres makes it very useful for the production of stamp and cheque papers, and such papers as must have a very accurate register of the water-mark, and the close even surface, which no other fibre can give, is very highly prized for fine lithographic work. Some of the 'imitation art' papers made in this country with a very large proportion of esparto are the finest papers in the world for magazine printing.

The question of the proportion of sulphite wood and esparto used in the furnish is often decided by the respective price of the two materials. It is in the beating of esparto papers that many experiments have been carried out with new and revolutionary designs in beating engines.

Some of these have been quite successful, notably the Taylor and Tower beaters, in which the stuff is circulated by a pump, up a pipe to the roll, which stands at the top (see Figs. 23 and 24, pp. 82 and 83). The main objects of these beaters seem to be saving of floor space, quick circulation and a saving in power.

To get the best results from esparto it is essential that the preliminary treatment should be regular, and beater tackle should be kept in a uniformly correct condition.

REPULPING 'BROKE'—EFFECT OF ADDING BROKE TO THE FURNISH—BROKE AND WASTE

WASTE paper, properly treated, is an important and valuable raw material for the paper-maker, yet it would seem, from the inadequate space and appliances for dealing with the disintegration of broke which are found in most mills, that this department was seldom planned out at the beginning, but was added when the necessity was realised. Yet it is in this department that a great deal of money may be lost or saved. There are several methods of dealing with broke or waste paper so that it may be again used in the furnish. Wet doctor broke from press rolls may be carried to the beaters and packed in with the next charge. Broke that has been dried but not tub-sized is sometimes filled in and cleared with the other items of the furnish.

This, however, is a risky process, as even with the greatest skill and care it is often the case that uncleared bits get into the chests.

The method employed must be one that is best adapted for the particular qualities made, and will depend on whether waste paper bought from outside the mill is used. So we find that nearly all mills have their own methods, of which the following are typical:

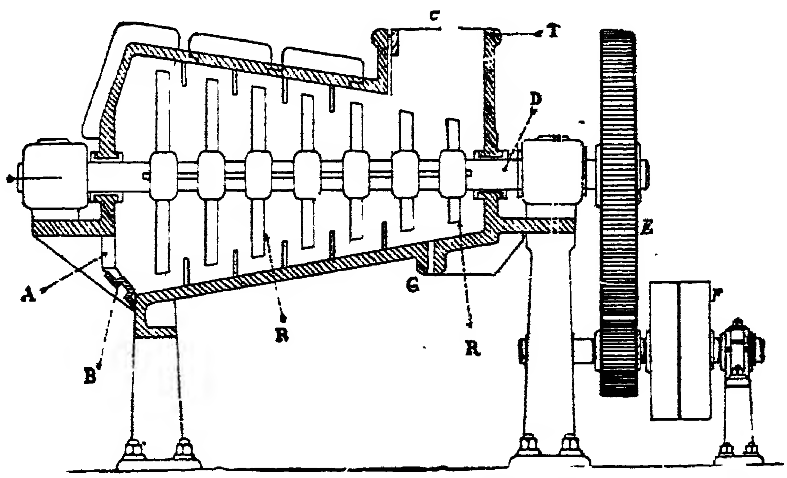
1. Soaking in tanks.
2. Boiling or scalding (either in stationary or revolving boilers).
3. Breaking in potchers with hot water, followed by steeping in draining tanks.
4. Boiling, followed by breaking, in edge runners, kneaders or pulpers.
5. Breaking in pulping engines with steam or hot water, without preliminary treatment.

From the above it will be seen that there are two essential requirements: (*a*) the soaking in water (generally hot) and (*b*) the mechanical action of defibring. To get good results these two must be combined in the process: (*a*) alone takes too long a time and too much space for tanks, with imperfectly soaked bits left to be dealt with by the beaters; (*b*) requires too much power without (*a*) and is useless for reducing hard-sized papers.

1. *Soaking in Tanks.*—This method is used mostly in mills making low-grade papers, such as middles or wrappers, where the presence of uncleared bits is of little consequence. The paper, mostly waste paper of low quality, is put into tanks with water, the charge being pressed down with poles in order to save space. After soaking for one or two days the pulp is dug out and filled into the beaters.

2. *Boiling in Rotary Boilers.*—The two essentials are combined by this process, but the disintegration is not complete unless after prolonged treatment. Paper that has been boiled is reduced in 'quality'; if the boilers revolve at a sufficiently high speed—3 revolutions per minute—excellent disintegration is obtained. If too much water is used, size is boiled out and is lost, and the strength of the fibres is very much lessened.

For this reason, many paper-makers prefer to defibre the broke by means



[*Messrs. Masson, Scott and Co. Ltd.*

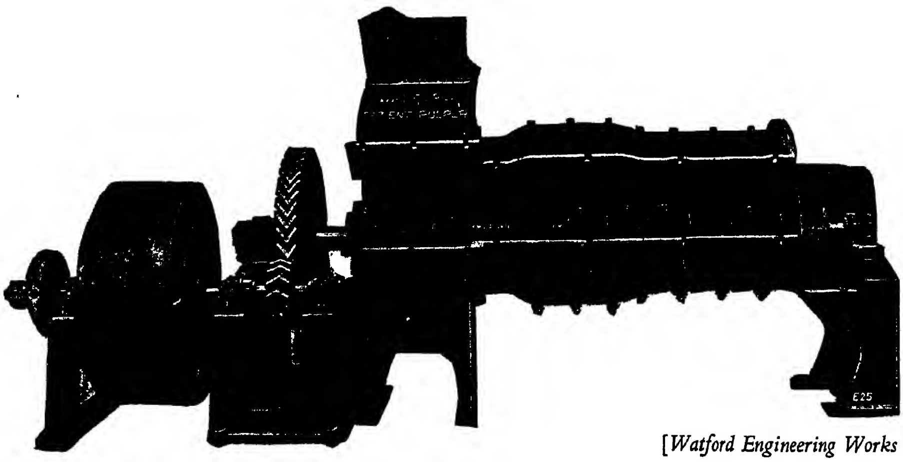
FIG. 33.—THE 'PERFECT' PULPER: SECTION SHOWING THE REVOLVING SHAFT AND FIXED ARMS

of a kollergang or kneader after a light boil in either a stationary or rotary boiler.

3. *Breaking in Potchers followed by Steeping in Draining Tanks.*—An old hollander beater is generally used. The broke is filled in with water and heated by blowing in steam to nearly boiling point. After the potcher has been fully charged the broke is roughly broken for a short time and then run into draining tanks. When the water is drained away, the pulp is dug out for the beaters. This is a very expensive way of treating broke, owing to the power required to break the paper and the steam used to heat the contents of the potcher.

4. *Breaking in Special Pulping Engines with Steam or Hot Water, without Preliminary Treatment.*—This is the best and cheapest method and is now being

used by all up-to-date mills. Among pulpers one of the most popular is the Perfect Pulper (Fig. 33). This machine consists of a cast-iron shell of conical shape, within which is a revolving shaft, on which is fitted a series of curved iron teeth or arms. The inside of the conical shell is also studded with shorter teeth, between which the revolving arms turn. At the smaller end of the cone is a hopper into which the broke is fed together with a supply of hot water for hard papers or cold for softer stuff. At this end the teeth are short and stout, gradually increasing in length to fill the cone, so that the pulp travels towards the larger end as it is broken up, the longer ones having the more disintegrated pulp to work through. The revolving shaft and teeth have a speed of 50 to 60 revolutions per minute and form a sort of screw, which gradually draws the stuff to the discharge opening. The conical casting



[*Watford Engineering Works*

FIG. 34.—WATFORD PATENT PULPER

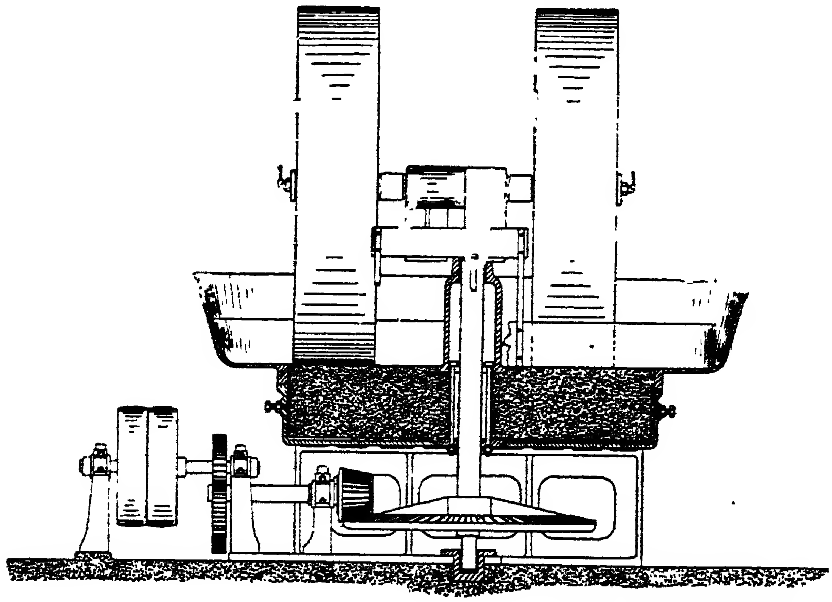
is in two parts, of which the top half is hinged for obtaining access to the interior. The action is continuous, but may be made intermittent if desired by closing the discharge doors. The output is from 6 to 20 cwt. per hour, according to the size of the pulper and the quality of the broke. The power required is from 15 to 36 h.p. Hot or cold water or steam may be used while feeding in the stock, but only soft papers can be properly pulped without heat. No colour, size, loading or fine fibres are lost by this method of pulping. Another very popular machine of the same type is the Watford pulper.

Some pulpers are still in use which work with intermittent charges. These are similar in construction to the dough mixers which are used in bakeries. They consist of metal troughs in which revolve two curved arms with serrated edges. The trough is gradually filled with the stock and a supply of hot water. The broke is usually disintegrated by the time the pulper is fully loaded, which

is a slow process; when ready, the whole vat is tilted with the help of heavy counterweights, and emptied into trucks.

The Edge Runner or Kollergang (Fig. 35).—This machine is peculiar and clumsy-looking in construction. It consists of a rather shallow circular vat the bottom of which is of hard stone, usually granite. Through the centre is a vertical shaft, driven from below. At right angles to this shaft, and forming a T, another shaft carries two stone rolls, which partly roll and partly drag on the stone bottom of the vat.

These rolls are on opposite sides of the vertical shaft, and cover all the stone bottom, slightly overlapping each other. A usual size of roll is 6 feet in diameter, 10 inches across the face and weighs about 3 tons. They are usually of



[*Messrs. Masson, Scott and Co. Ltd.*

FIG. 35.—SECTIONAL VIEW OF KOLLERGANG OR EDGE RUNNER, SHOWING DRIVING MECHANISM AND BASE STONE

granite with the running faces roughened to grip the pulp. They are driven from 10 to 15 travel revolutions per minute. The power required is about 30 h.p. and the output with strong papers 4 to 6 cwt. per hour.

A steel scraper or blade follows the rolls round the vat and pulls the stuff from the outer edges under the rolls for treatment. Sometimes the stone bottom is made concave and the faces of the rolls are cut to correspond to induce the pulp to fall under the rolls by its own weight.

The action of the edge runner is not only a rolling one—it is something more. The stones being pulled round in a small circle, there is also a twisting or screwing motion going on, similar to what takes place when a garden roller is turned in a small space.

In fact, the action is about the nearest that can be obtained by mechanical means to the pestle and mortar of the primitive paper-maker.

Although the power consumed is rather high compared to that of the pulper for its output, it must not be forgotten that the pulp is not only defibred but fibrillated, which is *power saved in the beating engine*. Therefore it is still popular among paper-makers who are wise enough to recognise its value in this respect. For some qualities of broke and waste paper it is a necessity, such as imitation parchments, krafts, or other specially treated papers, which it is nearly impossible to defibre by any other means. As against this, it has the disadvantage of reducing to fine particles any foreign materials in the pulp. These cannot then be got rid of very easily, as the fibres carry them round the sand traps and through the strainers.

Also, the edge runner requires a very heavy and secure foundation and constant and close attention from the engineer to ensure safety for the workers.

In dealing with miscellaneous waste paper, the edge runner produces results which more than compensate for all its faults. A very important matter in connection with the kollergang is its proper lubrication; it must be carefully and regularly lubricated and the bearings kept cool, otherwise the stones may crack and become useless.

In order to get the full value of broke from various qualities of paper, a great deal of space is necessary. It is obvious that the broke from an all-rag paper is of much more value than that from an esparto printing, and to take full advantage of that value, the former must be utilised in a similar paper. This necessitates the broke being kept in separate lots until that, or a similar variety, is again being made. This applies especially to coloured broke, which may have to be kept separate for quite a long time.

Very few mills have space for this purpose, and a great deal of good quality broke is sacrificed by being put into cheaper grades of paper.

All broke that is being kept for future use should be packed in good clean bags or press packed into bales and stored in a dry place, well away from dust and oily machinery. Before going into the boiler or pulper, all broke should be passed over a sorting table with coarse wire mesh top, and well shaken to get rid of dust and foreign material.

Bought waste paper requires to be sorted by skilled sorters in the same way as rags, if it is to be used in good papers, even when bought from waste-paper merchants who grade their paper into special qualities.

The Effect of adding Broke to the Furnish.—A great diversity of opinion is observable among paper-makers as to the effects of adding repulped paper to the furnish. No general statement can, in our opinion, be made. The circumstances of each particular case may differ so much that quite opposite

effects may be obtained by apparently the same causes. The only way of giving any sensible explanation is to give instances.

In the case of a machine making waterleaf paper, high-class writings or drawings for hand-sizing, or blottings, with no resin size, alum or loading, it would seem that no doubt would arise as to the effect of adding, say, 10 per cent of the same paper in the waterleaf condition.

It is the fact, however, that the stock may be made either more 'free' or more 'wet'. If the broke is taken straight from the machine to the beater and added to stuff nearly ready to be put down to the stuff chest, the result will be a freer paper. Under these conditions blotting paper will acquire a hard and harsh 'feel'.

This is owing to the fibres having lost their saturated condition coming over the drying cylinders, and to the time in the beater required for pulping being insufficient for them to become again saturated to the same extent. Also, no doubt, some of the finer fibrillæ will have been lost through the wire and suction boxes.

Now, if the broke is filled in with the furnish at the *commencement of the beating*, the fibres will become thoroughly saturated with water and become more highly fibrillated than when first run over the machine, producing a wetter stock. Thus the same quality of broke added at different periods of beating will give two different results. Waterleaf broke that has been stored long enough to have regained its normal hygroscopic condition will invariably, on being repulped, reach the machine in a wetter condition than when it was first made. In this instance the fibres have had time to soften and lose the tension or stress set up by the heat of the drying cylinders, and in a lesser degree by the pressure of the couch and press rolls, and are immediately susceptible to additional fibrillation.

If the broke is packed into the beater in sufficient quantity to increase materially the consistency of the stuff, higher fibrillation is certain.

Broke from tub-sized papers always produces wetter stuff. In most cases it is added in a given quantity with the furnish in the beater, and if it has not been boiled or overheated, the size (gelatine and resin) will still be effective and give hardness and cohesion to the sheet.

Also it shortens the beating time considerably, since its treatment in the pulper or edge runner has produced more fibrillation, and the beater takes up the work at a point a good deal further advanced than when the stock was first made into paper. The other items of the furnish will not require so much beating as they otherwise would, the fibrillæ necessary being supplied from the broke. For this reason all broke from strong papers should be kept for use in the same quality.

Engine or resin-sized broke, usually a lower grade of stock (wood or wood and esparto or straw), has rather a different effect. It produces a paper that feels more pliable and refined than can readily be obtained without it, even after longer beating of fresh fibres. This is especially noticeable with broke that has been through the edge runner, but pulper broke has this effect also, though in a lesser degree. This is no doubt owing to the action of these machines having more of a softening and fibrillating effect on the fibres than the beater.

A very great deal depends on how the broke was beaten in the first place. Broke from fine, free-beaten stuff will usually reduce the strength of any paper into which it is introduced, since the operations of pulping, clearing, etc., must of necessity reduce the length of the fibres still further. This must be borne in mind when using broke in the furnish for thin substances, particularly those with a water-mark, when the too lavish use of poor broke will cause a deal of trouble with pick-ups at the dandy roll. With heavier substances, water-marking will be assisted, the letters on the dandy roll sinking well into the layer of soft, fine fibres on the surface of the web.

Again, broke, even fine, short-fibred stuff, will increase the strength of paper as in the following instance:

It sometimes happens that a chest of stuff is found to be too raw—*i.e.* insufficiently fibrillated. The resulting paper will have a dull water-mark, a harsh feel, and be lacking in strength. An esparto paper beaten thus will give trouble by sticking to the press rolls.

By adding about 10 to 15 per cent of well-cleared broke, the rawness of the stuff will be overcome and the water-mark improved. The strength will be increased because the broke fills up the interstices of the sheet and forms a binding for the long raw fibres. The surface is made more level and uniform and the press rolls do not so readily pluck up individual fibres. As broke usually causes increased shrinkage on the drying cylinders, it may be used to assist in getting the correct register of water-marks. Increased retention of loadings, heavy colours, closer finish, etc., are also gained. Most paper-makers will agree that they would always add broke to the furnish if it were available.

Broke and Waste.—In a mill where there are a great many changes of deckles, etc., owing to the making of small lots, and many different grades and colours, there is, unavoidably, a great deal of broke and more or less waste of fibres. It is essential that this broke and waste be minimised as much as possible, and this depends on the efficiency of the machinery and the skill of the workers in handling it; also on the care taken in the handling of rags, half stuff, reels, sheets, etc. Trucks of rags and half stuff should never be overloaded or piled

up above the level of the edges. An overloaded truck is hard to push about and pieces from its load fall on the floor and are carelessly put back, with sand, dirt, or grease adhering, or flung away as waste.

In filling the beaters, no stuff should fall on the floor, but as it is not possible to avoid this on occasion, the floor at the beater side should be kept perfectly clean. There is no reason why this cannot be done, as, with any decent flooring, a flush with water and a sweep off with a broom ought to remove all dust and grit that can adhere to half stuff.

The beaterman should watch his stuff chests carefully so as to avoid overfilling.

The making machine department is where waste is most likely to be caused and broke to be made. Some of the broke is unavoidable; the paring that is left in order to cut off the deckle edge is an instance, and the paper run while changing deckles, dandy rolls, etc. But though a certain amount of broke is unavoidable, a machineman who takes an interest and pride in his work will try to carry through his changes so that the least possible broke is made. He should make certain in good time that the dandy roll he is going to put on is all correct, so that it will not be necessary to take it off again for cleaning or repairs. As to changes of deckles, etc., it is a good plan for him to work these out on a sheet of paper beforehand, and inform his assistant exactly what he is going to do, and why, so that he can have intelligent assistance at any moment in response to a signal, without loud shouting and confusion.

With regard to the paring or allowance made for cutting off the deckle edges of the web, this must be closely watched. With deckles of about 72 inches, 2 inches are sufficient for rag papers of ordinary quality. This gives 1 inch each side before tub-sizing and ½ to ¾ inch after sizing. Very strong all-rag papers will require 2½ inches, to allow for the greater shrinkage in sizing. Banks, which are apt to have ragged and lumpy edges, and do not, on account of their thin substance, stand well up to the ripping discs of the cutter, may with advantage be allowed 2¼ to 2½ inches. Engine-sized papers of fair substance will be all right with 1 to 1½ inches. Reels that are wound unevenly or slack are a prolific source of broke during later operations, and reach the cutters in such condition that accurate cutting becomes a matter of the greatest difficulty, the cutterman having to keep shifting the brackets in order to keep the web in a central position. It would be an endless task to enumerate all the causes of broke in the machine room, such as 'pick up', 'felt rubs', etc.; it must be left to the attention and skill of the machineman to keep these in check. A few words might be said, however, about the waste of fibres in starting up and shutting down the machine.

In shutting down a machine to 'wash out' for a fresh lot, the machine-

man will be guided by circumstances. If colour and furnish permit, the stuff service system need not be emptied, and here the sequence of colours, furnishes, etc., is important.

Waste occurs every time a chest has to be washed out, and by arranging lots in proper sequence, starting from a low shade and working up to yellows and blues, for instance, this waste will be cut down to the minimum. The stuff gate being shut, more water should be put on and the level of the shutes and strainers maintained until the stuff loses so much consistency that the wire can no longer form it into a web. The machine may be slowed and the stuff run up the press roll when the proper substance is lost. This will save a great deal of fibre that might otherwise be run down the drain.

When it is necessary to empty the chests and service system, the simplest plan is to run a good supply of water into the chest when the pump shows signs of losing grip. The pump will take the water from the chest and flush the remainder of the fibre from the pipe and stuff box. The pulp recovered by these means may not be so clean as the ordinary broke, owing to the flush of water disturbing the sand traps, but it may be used with care in lower qualities of paper. When it is realised that in the bottom of the chest, in the stuff pipe, stuff pump, stuff box, shutes, strainers and connecting pipes, there may be from 50 to 200 lb. of fibres, the importance of a little care in this connection is manifest. A careless shut-down may easily cost the mill £50. Again, when starting up it is a very wasteful and reprehensible practice to run the first flush of water and stuff down the drain in order to get full weight on putting the wire in gear.

The machine should be slowed down, so that a start can be made with the first flush of stuff. It is quite a simple matter to speed up after a few minutes.

When starting up the machine it will be found that the paper does not come up to the proper shade for some time. This is due to the use of fresh water at the start, and when the backwater begins to circulate, the colour loading, etc., gradually work round. In very deep shades the colour will be nearly ¾ hour before it is quite settled. Ordinary white paper coloured with a little ultramarine blue will come up in 15 to 30 minutes.

Also, no doubt, however well the machine has been washed up, the paper will contain specks of dirt, strings of fibres from the strainers and bits of coloured pulp from the previous lot. In some mills it is customary to run the web up the press rolls for a time on starting. Others get the web right away to the reel as soon as possible. In the first case the wet broke is easiest to repulp, but has the disadvantage that the handling of it is more difficult and often leads to its getting dirty. In the second case the machinemen, once the paper is

on the reel, can get the substance, dandy register and drying right, and by the time the colour has been approved the paper is correct. A fresh reel can then be started and the first piece torn up.

Most paper-makers are unwilling to tear up as broke any paper that has been run on the reel, and are tempted to let the doubtful start go through in the hope that some of it will be good. But if the paper is intended for tub-sizing it must be remembered that the size used for the bad sheets is waste, and so is the labour of cutting and sorting.

In the following operations of tub-sizing, drying, etc., close attention on the part of the workers is necessary at all times to prevent blemishes and breaks. Slips or sheets, torn from the reel at the machine, are frequent causes of broke, and the fewest possible should be taken by the machinemen, and these should be flagged.

Broke must not be allowed to be about on the floors to be trodden on and thus rendered useless for repulping; cleanliness of the floors, machinery and the *hands of those who touch the paper* is imperative.

RESIN SIZING—STARCH—SILICATE OF SODA—ALUM—LOADINGS

RESIN, rosin or colophony is the solid residue of the gums or juices of coniferous trees after the evaporation of their moisture and volatile substances. It is a weak acid, to which the name abietic acid is given. Its colour ranges from a light pale yellow to a dark brown, according to its source and the temperature used to drive off the volatile substance. It is insoluble in water, and, when broken, the fracture shows a clear, glassy surface.

When exposed to light and air, resin changes into a crystalline substance, becomes friable and loses its amorphous quality. This explains why resin-sized papers gradually deteriorate, losing colour, strength and ink resistance.

Resinate of soda, resin soap or resin size is made by boiling resin with soda ash or with caustic soda. Resin size is soluble in water, but there is always a certain amount of free resin present, unless the soda has been used in such proportion as to balance exactly the acid resin, when the size is called neutral. Size which has much free rosin (20 to 25 per cent) is of a creamy or white colour, and is called 'white size', to distinguish it from the other, which is brown in colour.

Resin size is generally made by boiling powdered resin with a solution of soda ash in an open steam-heated vessel, the proportions being about 1 lb. of soda ash to 6½ or 7½ lb. of resin. This would produce a size with about 10 to 15 per cent of free rosin with 7 hours' boiling. Those paper-mills which make their own size have found by experiment the proportions that are most suitable for their stock and for the hardness of their water.

Although it is about 130 years since resin was first found to have sizing qualities, it still remains a matter of controversy as to the exact action which causes it to be a sizing agent. It was held for a long time that resinate of alumina (the precipitate of resin size and sulphate of alumina) was absorbed by, or stuck to, the fibres, and filled up air space in the paper in much the same way as gelatine size does.

Modern chemistry offers another and more probable explanation. In the mixing of the relatively small quantity of size in the beater of stuff and water,

the size is so much diluted as to be resolved into its component parts, free resin and sodium hydroxide. In the same way, hydrolysis of the sulphate of alumina produces, in its place, sulphuric acid and aluminium hydroxide. The sulphuric acid and sodium combine to some extent to form neutral salts, thus leaving as effective agents for sizing the *free resin particles* and *particles of aluminium hydroxide.*

Now, research into electro-kinetics has shown that some substances are charged with positive and some with negative electricity. Substances of opposite charges attract each other. It will at once be seen that this has a vital bearing on the subject.

Fibres suspended in water are charged negatively, so also are the minute particles of resin. Therefore the addition of resin particles to the beater will not result in the fibres being covered by the resin. They will be repelled instead, and anyone who has watched the behaviour of stuff and resin size in a beater before the alumina has been added will at once perceive that some disturbing action is taking place which seems to be too great to be accounted for by the formation of gas, causing an increase in bulk.

The particles of aluminium hydroxide, on the other hand, are charged with a positive charge. On the addition of the alum solution the disturbance in the beater subsides and the stuff contracts in bulk. The cellulose has attracted to itself the positively charged aluminium, and as this is always added in excess, it may be concluded that the negatively charged fibres have now become positively charged, or at least coated with the positively charged aluminium particles. Thus the fibres are now in a condition to attract the negatively charged particles of resin, when we may assume that the action has ceased.

The excess of alumina assures that no resinous particles will remain unattracted by the fibres or by the alumina particles.

On passing over the machine, some of these wandering particles of resin and alumina will pass through the wire with the water, but the bulk remains on or between the fibres, forming an ink-resisting coating or filler for air spaces.

It has generally been assumed that the resin size must be first added to the stock in the beater, so that it may be 'beaten into the fibres', but this theory seems to indicate that the opposite would be more effective. Indeed, many mills *do* hold this to be the case, and put the sulphate of alumina solution into the beater first, to neutralise the hardness of their water, and find their sizing improved thereby.

Bewoid Size.—For years paper-makers have been looking for a method by which resin may be incorporated in the finished sheet without the use of alkali and alum. Until the advent of the Bewoid sizing process the nearest approach

to this ideal was the making of resin size with the alkali so proportioned to the resin that a certain percentage of the latter was uncombined. This can be carried only to a very limited extent (the product being called 'white size'), as, in practice, the less alkali used the greater is the liability for the 'free' resin to coagulate and cause specks to appear in the sheets on its being glazed. As the alkali is increased to prevent this happening, so also must the quantity of alum required to neutralise it be increased. The greater the quantity of alum required, the greater will be the amount of sulphuric acid liberated in the beater. Besides being a very active agent in the deterioration of the paper, this free acid is very destructive to the beater plates and bars, and the paper machine's wires and equipment generally.

The ideal size, therefore, is one which requires no more alum than is necessary to neutralise the alkaline substances in hard water, and to attract the particles of resin to the fibres.

The Bewoid process, which was the result of years of research by Dr. Bruno Wieger, of Brunswick, Germany, goes far towards fulfilling these conditions. Bewoid colloid is practically a mechanical mixture of resin and water. It contains 45 per cent resin, all of which is free—that is to say, in its natural unhydrated state. In manufacture the resin is first melted, then mechanically dispersed in the special Bewoid mill. From 1 to 1½ per cent of caustic soda is run in, and a small quantity of casein or gelatine is added, which covers the particles of resin with a very thin protective coating and maintains them in suspension. The finished size is a pure white colour and only slightly alkaline. The alum required is therefore very much reduced, in some cases by 50 per cent, and frothing is eliminated. As this size does not require to be 'beaten in' it may be added to the beater as it is being emptied, or run into the stuff chest with the alum, this avoiding the corrosive action of the alum in the beater.

The Bewoid mill consists of the following parts: A steam-jacketed cylindrical pan of 125 gallons capacity, with a manometer, safety valve, blow-off cock, and steam trap. The vertical spindle extends through the bottom of the pan to a ball-bearing, and continues through the top, with bevel wheels, to a horizontal shaft fitted with two specially designed impellers. This is arranged to run at 70 to 200 revolutions per minute by means of a two-speed motor. There is also a measuring vessel of 130 litres capacity graduated in 20-litre divisions, with a 2-inch and ½-inch run-off pipe to run into the Bewoid mill. The measuring vessel is supplied with a steam- and water-pipe. There is also a small copper measuring vessel of 7 litres capacity on a tripod stand. The method of preparation is as follows: The resin, 560 lb., is melted without water in the Bewoid mill. Melting is assisted by circulating at the slow speed.

When European resins are used, the resin should be brought up to a temperature of 140° C. during melting, so that any crystals of a high melting-point will be melted and dissolved. When the resin is melted the steam is turned off, and agitation started at the high speed; 9 lb. of caustic soda in solution is run in slowly through the 7-litre vessel. While this is running in the casein solution is prepared; 20 litres of water is run into the 130-litre vessel. The steam which is taken to a jet at the bottom of the vessel is turned on and 12 lb. of casein tipped in. With the steam still on, 1 lb. 2 oz. of caustic soda in concentrated solution is added, and the solution stirred quickly. The

[*Becker and Co.*

FIG. 36.—BEWOID MILL, SHOWING STEAM-JACKETED PANS AND MEASURING VESSELS

temperature should not be higher than 82° C. This is diluted to 60 litres at 33° to 43° C., depending on the melting-point of the resin. When mixed, a further 1 lb. 2 oz. of caustic soda is added.

When the 9 lb. caustic solution is all added to the resin, it is necessary to cool the resin further to 100° C. This can be done with water, or more conveniently by using part of the casein solution through the ½-inch pipe. The correct temperature is easily observed by the sudden drop in the amount of steam given off. If casein solution is used for this cooling, the amount used must be replaced with water, and the bulk and temperature of the casein solution brought up to the original figures. This 60 litres of casein solution is run into the resin through the 2-inch pipe.

A rosin-wax size can also be produced by the Bewoid process. This may

be used for special papers, but has the effect of reducing strength and making a limp and flabby paper.

After 5 minutes the dispersion is diluted with water at 38° C.: first, 70 litres through the ½-inch pipe, and the remainder through the 2-inch pipe. As the colloid rises up the sides of the pan during dilution the slow speed is started, and the mill is finally filled and the agitation stopped. When filled, the size is of 45 per cent concentration.

Skin glue can be used as a colloidalisator in place of casein. This gives improved sizing, but the colloid is less stable.

When using glue, only 8½ lb. are used at 50° C. in 60 litres, without caustic soda. The glue should be soaked for ½ hour before using. Only 8 lb. 6 oz. of caustic soda is used instead of 9 lb., as when using casein, for the first cooling and neutralising of the resin.

Starch.—In very ancient times starch was the only material known for the sizing of paper. It is now used in addition to other sizing agents to give a hard rattle and an improved finish to paper. A slight increase in strength may also be obtained by its use. It increases transparency, especially in highly glazed papers.

A great deal must be used to get much result, as it readily drains out on the wire and suction boxes. As it is carried mechanically by the fibres, the size of starch granules is important. Those of potato starch are largest, maize smaller and rice smallest of all.

Each granule is a little capsule or container filled with a gelatinous substance. The heat of the drying cylinders, acting on the wet granule, causes it to swell and burst, the contents fusing and binding the fibres together. Starch is better retained by the stock in the presence of sodium silicate in the proportion of 1 pint of sodium silicate to 5 lb. of starch. These may be mixed together with warm water, then heated until the starch is partly 'burst' and cooled with a little cold water to stop the action. This is called starch silicate; the precipitate is very white and has more hardening effect on the fibres than starch or sodium silicate used alone. About 2 pints of silicate and 10 lb. of starch are required for 4 cwt. dry weight of stock. Less resin size is used in this case.

The usual amount of alum has to be slightly increased to precipitate the starch silicate thoroughly. Starch is, however, an expensive material to use, and in free beaten stock its effect may be entirely lost. In well-fibrillated stuff, which carries the granules in greater quantity, its results are more apparent.

Silicate of Soda.—The use of silicate of soda ('waterglass') as an auxiliary sizing agent is gradually becoming more general, and excellent results may be obtained by using the silicate either alone or, more often, in conjunction with resin size and starch.

The silicate is a compound formed by the fusion of silica with carbonate of soda, and at ordinary temperature it is a thick, syrupy, sticky liquid which hardens on exposure to air. It is readily soluble in warm water, and it is often necessary, especially in cold weather, to add warm water to it before furnishing to the beater. If this precaution is not taken, the silicate sinks to the bottom of the trough and lies there, forming a hard, glass-like coating.

Silicate of soda is an alkaline substance, and is precipitated by alum, in much the same way as resin size. It does not actually resist aqueous inks by itself, and for this purpose requires the addition of resin size, the retention of which, along with starch, colour and fillers, it greatly assists, so that it may ultimately help in the production of a more ink-resisting paper.

Silicate increases the strength of most papers, drying hard and white, and it also gives a greatly increased rattle and firm 'handle' to all papers. It may be used with advantage to assist in making the stuff work 'wet' on the machine, as it helps in the retention of water in poorly fibrillated or 'free' stuff.

As it is very resistant to oils, the silicate may be used to great advantage in the making of printing papers and posters which have to resist an enormous amount of coloured and oily inks. It also has the effect of assisting the paper to resist the deteriorating action of sunlight.

While resin-sized papers are often inclined to be sticky at the press rolls, silicate of soda helps to eliminate this trouble, and it also reduces cockling and drying defects and helps the paper to lie flat when cut.

The cementing action of the silicate on the fibres keeps down fluff, and this is very beneficial in papers which have to be clearly punched or perforated with small holes or cut into narrow strips.

Silicate of soda may be used to replace part of the resin size, and thus reduce considerably the cost of sizing, or it may be used as an auxiliary sizing agent, along with the usual amount of resin size. In this way it will impart additional qualities to the paper, such as hardness, 'snap' and increased strength.

When the silicate, along with the requisite amount of alum, is added to the beater, a light and bulky precipitate is formed in contact with the fibres, and as the precipitate sticks to the fibres themselves, most of it is carried across the wet end of the machine and is not lost in the back water.

It is also claimed that the precipitate of silicate, which consists of aluminium oxide, aluminium silicate and silica, retains 25 per cent of its weight of moisture when passing over the machine under the normal conditions of drying, and this would assist in the subsequent calendering where a high finish is desired.

It is most important that sufficient alum should be used in the precipitation

of the silicate, as the silica itself gives a slightly alkaline reaction with litmus. The contents of the beater must therefore show a definitely acid reaction, otherwise a great amount of the value of the silicate will be wasted.

The proper order for the furnishing of the beater is to add first the silicate of soda and, after it has become thoroughly mixed with the stuff, sufficient alum to precipitate it completely. If resin size is also being used it should be added later, and, finally, the alum for the resin.

As silicate of soda is manufactured in many different forms of solution, differing in viscosity, density and alkalinity, great care must be used in selecting the most suitable kind for sizing paper.

The amount of silicate to be used depends upon the kind of paper being made, the substance of the paper and the effect that it is desired to produce. If it is desired to make a paper with a very hard rattle, as much as 3 or 4 per cent of silicate may be used, but to improve the hardness of a well-sized writing paper, ½ to 1 per cent will be sufficient.

Silicate may be used with great advantage in conjunction with starch. The starch-silicate is made by mixing the two substances in a predetermined proportion and heating with water to about 65° C. until the starch has burst. The mixture is then added to the furnish and sufficient alum added to precipitate the silicate.

Starch being much more expensive than silicate of soda, the proportion of silicate to starch should be carefully regulated in order to ensure the best sizing and hardening results at the lowest cost.

Paperine.—Paperine is a preparation of farina which is treated with caustic soda and acid to produce a cold water-soluble starch substitute. This material is much more economical in use than starch, being retained in the paper to a remarkable degree. Normally ½ to 1 per cent on the dry weight of the beater is sufficient to give increased strength and handle. It is best to add it dry to the beater, when furnishing in very small amounts, through a small open sieve, which prevents the formation of coagulated lumps. These are very difficult to dissolve and cause sticking at the press rolls, but with normal care there should be no trouble from this source.

Alum.—This important chemical compound finds many uses in the mill, and it can be truly said that it is an indispensable ingredient for most papers.

Aluminium sulphate, $Al_2(SO_4)_3$, is made in three grades. The best grade, which is used in good quality writing papers and other papers which have to be free from iron, contains 17 to 18 per cent aluminium oxide (Al_2O_3) and is practically free from iron. The second quality contains 14 per cent of aluminium oxide and a small percentage of iron, usually about 0.12 per cent

or less. The third quality, usually called alumino-ferric, contains considerably more iron than the other two, and is only used in low grades of paper; it is also used for the purification of water.

For the highest grades of writing paper, potash alum, $Al_2K_2(SO_4)_4,24H_2O$, or crystal alum is still used. This is an almost colourless salt of aluminium and potassium sulphates, but it is very much less soluble in water than the aluminium sulphates and much more expensive.

Alum or aluminium sulphate is generally made into a solution with water before being added to the beater, although it is the practice in some 'news' mills to buy it 'kibbled' or in powder and put it dry into the breakers.

The best way to prepare the solution is in wooden or lead-lined tanks or chests having lead pipes and taps. Iron or brass must not be used, as the free acid will eat these away. Wooden tanks are usually provided, two for dissolving the alum and a third and larger tank as a store, from which the solution is run by gravity to the beater room or carried in wooden buckets.

A satisfactory method is to have a wicker cage or basket which will conveniently hold the contents of one or more bags of alum, and suspend it by means of a wooden pole across the top of the tank at such a height that the water in the tank can reach well up the cage. The alum is put into the basket and the tank filled with water. As soon as the water reaches the alum it readily dissolves, and the saturated solution sinks down in the chest, allowing fresh water to reach the alum. The action may be accelerated by rocking the basket on the pole or by causing the circular cage to revolve.

The saturated solution will stand at about 62° to 64° Tw., and a gallon of the solution will contain about 3½ lb. of aluminium sulphate. For convenience in working in the mill, the solution may be diluted to 20° Tw., in which case a gallon will contain about 1 lb. of alum.

The chief uses to which alum is put in the mill are:

1. For the precipitation of resin size.
2. For the precipitation of starch.
3. For the precipitation of silicate of soda.
4. To brighten the colour of the paper.
5. To help the resistance of the paper to ink.
6. To soften the water if it is hard.
7. To prevent or lessen frothing at the machine.
8. For the preparation of gelatine size for tub-sizing and to prevent putrefaction.
9. To assist in the bleaching of rags.
10. As a mordant for certain dyestuffs.

The acidity of sizing agents is now controlled by pH value, as are many other reactions in the paper-mill.

A solution of alum is always dirty and full of jute, hairs, etc., from the bags in which it comes, so that it must be carefully strained through flannel over a fine-mesh wire cloth when it is being put into the beater, or it may be strained when being run from the dissolving tanks to the store tank.

The furnishing of dry alum direct into the beaters is not to be recommended, even in news mills, as the hairs and other impurities contained in it foul the sheet, and also are frequently the cause of breaks at the machine. The provision of proper dissolving tanks is a simple and inexpensive way of avoiding this trouble, and it is also more economical in the long run.

Loading.—There are two reasons for the loading of paper with mineral substances. The first, and no doubt original, reason is for the purpose of producing a cheaper paper by substituting loading for fibre. As there is no record of the introduction of this process, we may conjecture that some astute paper-makers kept the secret to themselves and reaped a rich harvest until it leaked out.

The second is that the use of loading, or fillers, imparts special properties to papers, and it is therefore a necessity for some classes of paper.

The most important of these fillers is china clay or kaolin. This is the remains of very ancient deposits of felspar or granite. Its chemical composition is about half silica (SiO_2). The other half is made up of about 35 to 40 per cent of alumina (Al_2O_3), 12 to 15 per cent of water and traces of various substances such as calcium, magnesium, iron, mica, etc.

It is found in Cornwall and Devon, but huge deposits exist in many other parts of the world. It is usually found close under the surface, and is dug out so that great pits are made. It is not usable without treatment, as it is mixed up with sand and grit, mica particles, etc., and must be refined and cleaned to be of any use to the paper-maker.

The clay is broken from the face of the pit banks by directing against it a jet of water at high pressure, or by men with picks, who break down the clay and direct it into a flowing stream of water. It is allowed to settle at the bottom of the pit long enough to let the heavier substances fall to the bottom and the clay suspended in the water is pumped to the surface. It then passes through 'mica drags' or shutes; the finer particles pass through screens, leaving mica behind. The stream of water and clay is then run to settling ponds or pits. From thence it is run to storage tanks and the clay falls slowly to the bottom, leaving the clear water at the top. The water being run off, the clay is dried in drying pans or kilns and broken up for use.

As may be expected, there are many grades of clay. The best qualities

are free from grit and sand, and the particles are very fine and white. These are used for coating papers. Most paper-makers' clays contain more or less mica, according to the quality, and this shows up in paper as glistening specks. Clay is of a colloidal or plastic nature when mixed with water. The old circulating tanks used in some mills, combined with strainers, to separate the clay from grit, etc., have in many mills given place to centrifugal machines, which are more positive and continuous in their action.

Another important filler is calcium sulphate ($CaSO_4$), known also as gypsum, terra alba in its natural state, and as pearl hardening, crown filler, satinite, etc., in the artificial production. Gypsum and terra alba are the ordinary mineral ground fine and have a crystalline structure. Pearl hardening is prepared by precipitation with acid and is of a fine white colour, clean and free from grit. It is partly soluble (1 lb. to 45 gallons of water), and therefore a great deal is lost if the back water of the machine is not well conserved. It can be used to improve the colour of high-class papers. As satin white, in paste form, it is used for paper coating.

Magnesium silicates in the form of asbestine, agalite and talc are sometimes used as fillers, the particles being of a fibrous form, and well retained by the paper; they are also 'soapy' and give a high finish. Barytes and blanc fixe are forms of barium sulphate. The latter is the precipitated quality and is sold in paste form for paper coating.

Almost every paper of any substance, except hand-made and some very expensive all-rag papers, contain mineral loading. All printing papers require china clay, which enables the paper to have a close regular finish, and is very absorbent of printer's ink, besides allowing a cheaper paper to be produced. It also takes colours well and brings up the brightness of the shades. Used in moderate quantity in blottings, it gives a soft smooth feel, taking away a good deal of the harshness of the fibres, and helps in the retention of the dyes, which in this case have to be used without a mordant.

Calcium sulphate fillers are not used to such an extent as china clay, but produce much the same results, except that they do not give the same limp feeling and are less inclined to make the paper soft and flabby.

All these loadings, however, reduce the bulk of the paper, being twice the weight of fibre, bulk for bulk.

A loading which has received much publicity during recent years is titanium oxide. The particular merit claimed for this material is that it imparts a greater degree of opacity than the commoner forms of loading. There is no doubt that used in the correct proportion, which varies according to the degree of opacity required, a superior result can be achieved in this respect, but it is a very expensive material, and it is doubtful whether the weight saved by enabling

you to get an opacity equal to a thicker paper pays for the cost of the titanium oxide which is necessary to achieve this result.

It has a very small particle size, and a closed back-water system or an efficient form of back-water recovery plant is necessary if the maximum economy in its use is to be achieved.

Opacity being necessary for papers such as envelope papers and printing papers, these are usually well loaded, china clay being the filler most in use. Writing papers may have up to 15 per cent of loading, usually china clay and terra alba in equal proportions; S/C printings up to 25 per cent of china clay, and in the case of imitation art, as much as it will carry, which, of course, depends on the substance and may be as high as 30 per cent. A good heavy filling of china clay reduces the expansion and contraction of litho papers.

The retention of loading varies considerably. China clay may be retained to the extent of 80 per cent of the quantity put in the beaters, but is usually about 50 per cent unless a closed back-water system is used. The retention is governed by many factors, the chief being the degree of fibrillation of the stock, the thickness of the paper, the nature of the loading, the characteristics of the fibres used, the formation of the sheet on the machine, the size or other binding substances put in the beater, the conservation of the back water and the length and flow of the machine shutes.

Well-fibrillated stock, and fibres that are very fine and pack closely in paper, such as esparto and straw, have a high retention. Free stock for blottings and harsh fibres like soda pulp from coniferous wood have a low retention.

Papers that are heavily resin-sized or have starch, silicate of soda or other binding substances will carry a heavy percentage of loading.

The formation of the sheet on the machine will, of course, depend on the beating of the stuff, but too much water on the wire will mean a loss of loading by excessive suction on the boxes. Up till recently it has always been an established practice to add the loading—whether it was clay, chalk, or other mineral—to the beater, it being always maintained that if the loading were well beaten into the stuff a greater proportion was carried through into the paper, and less came away in the white water; this theory has been found erroneous. Much better results are now being obtained by adding the loading with water in a thin continuous stream to the stock before it goes on to the machine, before the strainer. In this way there has been found to be a saving in the amount of loading required to give a predetermined quantity in the paper. Opacity has been improved, and less loading has had to be dealt with in the back water. There is the additional advantage that the beaters hold more stuff and the beater bars and plates last longer, owing to the absence of the abrasive action

of the clay. The bottoms of the chests and shutes are not filled with loading, and lastly the centrifugal machines are not rapidly filled with large quantities of loading in the bolsters. This method of adding loading gives much greater control over the quantity, and the amount being carried in the paper can be altered in a minute or so instead of having to wait for another engine, or a chest of stuff to be worked out.

DYEING OF PAPER—MINERAL AND INORGANIC DYES—THE USE OF ANILINE DYES

Dyeing of Paper.—The colouring of paper to shade is the most baffling process in paper-making. It is intricately connected with quality, beating and making. By quality we mean not only difference in fibres as between, say, cotton and esparto, but any difference in quality of the same fibres. No two consignments of fines, seconds or other kinds of cotton rags are ever so much alike as to produce identically similar fibres. All other paper-making materials are subject, more or less, to variations, both in the condition in which they come to the mill and in their subsequent treatment there. For example, wood pulp, which is the most regular of all supplies of fibre when obtained from the same source and of the same brand, will be found to vary in colour, strength and purity. This may be from causes quite beyond the maker's control, such as the condition of their raw materials, the logs from the forest, the chemicals they use to reduce the wood to fibres, their water supply and many other causes, some of which are known and guarded against as far as possible, while others are still matters of mystery. The paper-maker knows this, and if the variations are not great, he has to accept the supply and make the best he can of it. Unfortunately, he does not find the paper consumer quite so complacent, and must direct all his skill to eliminate these differences and make up deficiencies in colour, quality and strength by any means he can devise.

Rags are by far the most variable of raw materials, and unless great care is taken in their mill treatment, the resulting half stuffs may have extreme differences in quality. Apart from other things, colour will be the greatest difficulty. Suppose a high-grade writing paper is being made from fines, and the natural white colour of the bleached rags gives the correct shade to a standard sample. The next making from a different lot of rags may be dull or yellow compared to the first. The paper-maker may try to match his sample by tinting the stock with blue, or blue and pink. A fair match may be obtained, but careful examination in comparison with the previous making will show it to look 'coloured' instead of pure white. Then he may have to alter his furnish to get the desired tint by adding a certain percentage of white rags,

perhaps new cuttings, which brings up his costs and may absorb his profit for that making. In the meantime, as he must keep his machine running, he will have on his hands the paper made the dull shade when starting up, the 'coloured' paper and the paper made with the more expensive furnish, which may or may not be correct.

Thus the lot will have several 'shades', of which he will be notified in due course by the salle foreman, the paper salesman, the customers and his employer, all of whom will receive his explanations with obvious incredulity.

Paper made from uncoloured rag stock has a creamy tint. If the paper is desired to be whiter, we have to add colour to the stuff in the beater. The dye generally used is ultramarine blue.

This colour when used in small quantities gives a bluish-white tint, verging on green in some qualities. If the tone is desired to be creamy white, some pink must also be added.

Cheap printing papers and other papers made chiefly from mechanical wood are coloured with aniline dyes. The shades obtained with this mixture of blue and pink are infinite in number. The higher the quality and purity of the fibres, the less dye is required and the more brilliant is the colour. With good cotton fibres ¼ oz. in 200 lb. of stuff makes a decided shade, but that quantity would have little or no effect on wood pulp.

When we get to 3 or 4 oz. ultramarine blue in 200 lb. of stuff, the paper begins to show an azure tint, which gets deeper as more blue is added, until we arrive at what is called in the trade 'yellow'—*i.e.* half-way between azure and blue. Here again pink is employed to tone the azure to a richer shade as required.

The beating of the stock has a great influence on its retention or absorption of dyes. Free-beaten stuff requires more colour than fibrillated stuff. As no two beatermen beat exactly alike in making, the shade will probably vary as the differently treated stuff comes to the machine.

Other causes which produce differences in shade are insufficient or irregular bleaching, lighter or heavier filling in of the beaters, different shades of 'broke' in the furnish, careless weighing or measuring of the dyestuffs, too prolonged beating, insufficient or too much sulphate of alumina and resin size, dyes not thoroughly mixed with the stuff in the beater, stuff lying too long in the chests, agitators running too fast or too slow, changes made in amount of water used on the machine, and variations in weight, suction, couching, pressing, tub-sizing, damping or finishing.

Those mills which use surface or river water are subject to variations of its purity, which makes it very difficult to get the same colours in summer and winter seasons or in flood times. Where a machine has to run from one stuff

chest, every beater that is let down is liable to upset the shade. Where two chests are used alternately, there is less risk of shades varying except on changing from one to another.

As for the dyes, most of them the products of intricate chemical processes, the paper-maker has to take them on trust and find by experiment, often costly enough, their suitability for his stock and the matching of his samples. On long runs, apart from the start, when alterations to match the sample are being made, there is a fair chance of producing a lot with few variations in shade. But when making small lots, which most fine mills are compelled to undertake, the matching of samples quickly and accurately without making many shades is a serious and difficult task, which calls for long experience and knowledge of paper-making, and an artist's eye for colour or shades of colour. In a paper which may have half a dozen different dyes combined, the paper-maker has to judge quickly and accurately which one is out of proportion, and by how much or how little, and immediately put his judgment to the test by making the alteration.

Unlike the artist, who can alter the tints on his canvas as often as he pleases and presents only the finished picture as the result of his work, the paper colourman's alterations, correct or otherwise, are all shown by the shades in the paper.

The quantity of colour used to obtain the deeper shades of azures, blues and tints depends on several other factors besides quality and beating. Some of these factors are very obscure; for instance, the electrical charges in the dyes, and their relation to the electrical charge in fibres and in the chemical used to fix them. Certain dyes will dye or be absorbed by certain fibres very readily; others will require the aid of alum or other mordants before they will be of any use.

Colours that are not held by the fibres either mechanically or chemically are lost to a great extent in the back water of the machine. In addition to the actual value wasted, there is the difficulty of dealing with the effluent, which is so very obvious when allowed to run into a river. Inorganic dyes such as Venetian red, the ochres, umbers and paste pigments act mostly as fillers or loading, and are retained best by well-fibrillated and heavily-sized stock with an excess of alum. Ultramarine blue is of this class.

Aniline or coal-tar dyes are more readily absorbed by the fibres, and are retained so much better that the 'two-sideness' of deep tints is very much reduced. Unfortunately, this type of dyestuff is seldom fast to light and is therefore not often used for fine papers.

'Two-sideness' in paper is for the most part a beating question. Free stuff allows the drainage of water on the machine wire, and little suction is required on the first box to allow of a good water-mark.

On passing over the other boxes, the air is drawn readily through the sheet and carries the coloured water along with it. With highly fibrillated stock there is little loss of water on the wire, consequently a heavy suction is used to bring the stuff to the right consistency for water-marking. This pulls down the fine fibrillæ into the air spaces of the sheet, and the second and third boxes pulling heavily, take the colour from the fibres nearest the wire, but cannot influence the surface layer very much. In this case it is little use to instruct the machineman to 'use less suction'. He must use suction according to the wetness of the stock. If a paper equally coloured both sides is essential the stuff must be beaten free, so that it is *not necessary* to use so much suction, and if possible a dye used that is absorbed by the fibres instead of being mechanically held as a loading.

Also, the drying cylinders should be so regulated that the first really hot one comes in contact with the top side of the sheet. This ensures that if any reduction in colour is caused by the heat, the highest coloured side will suffer most, and the steam passing to the under side will diffuse some of the dye and convey it to that side.

Ultramarine blue suffers some decomposition by heat and steam, therefore it is inadvisable to use very hot water to dissolve it when putting it through the strainer cloth or to heat the stuff on the machine when running azures or blue. Smalts blue, which is entirely a loading, being really blue glass ground fine, makes a very two-sided paper, but it is perfectly fast to light, and resists acids, heat and moisture. It does not necessarily follow that a paper coloured with Smalts blue will never fade, but the fading will be due to the deterioration of the stock, which gives the same effect by lowering the tone of the ground shade.

During the last few years some dyes have been evolved which are practically sun-proof, but they have not yet come into general use in paper-making, chiefly owing to the extra cost.

Mineral and Inorganic Dyes.—Ultramarine blue is the principal colour used by paper-makers to counteract or hide the natural yellowish shade of the fibres. It is simple to use and fairly permanent, though not perfectly so. It is manufactured in many qualities and shades from a purple or reddish to a green tint.

It is not affected by alkalis, but is sensitive to the action of acids. Manufacturers of colours direct their energies to produce a blue that is little affected by alum. Some very good qualities of alum-resisting ultramarine may now be obtained at a very reasonable price, and it will be found cheaper in the long run to use a really good grade, even though it costs a good deal more than a doubtful one. Generally speaking, the finest ground blues are most efficient in colouring power. Before being added to the beater, the blue should be

strained through a fine-meshed strainer cloth or bag. Warm, but not hot or boiling, water can be used, and the colour well diluted, not more than 1 lb. to 3 gallons of water, and this only when a large quantity is being used. The stock must be definitely acid to litmus or the colour will not hold on the machine.

For this reason it is not suited to the colouring of blottings, which require a huge quantity to make any appreciable effect. Also, a blotting coloured with ultramarine in any quantity will be found to emit a disagreeable odour when used to absorb ink.

Smalts Blue is finely powdered cobalt-blue glass. It is quite unaffected by acids or alkalis, exposure to light or by atmospheric conditions. It is expensive to use, owing to the fact that about twenty times the quantity is required compared to ultramarine, and its first cost is high. It is found in hand-made writings and ledgers, and sometimes in high-class machine-made paper. In the latter case a great deal sinks in the sand traps and is lost, so that the modern paper-maker does not look on it with much favour and uses it only when it is specially asked for.

Prussian Blue.—This is a chemical pigment of a green shade. It is too green to use in white papers, but is very useful in small proportions in azures and blues that must have a greener tint than can be obtained with ultramarine. It is affected by alkalis, but not by acids. Formerly it was produced by a combination of chemicals in the beater, but it can now be obtained in the form of paste or powder, which give more regular results.

Yellow Chrome.—This also is a chemical pigment which may be made in the beater, but it is less trouble to buy the colour in paste form. It is a lead chromate and is very poisonous. The shade varies from a canary yellow to a brown or orange tint.

Carbon Black.—This is a very useful pigment to have in the mill. It produces grey tints and can be employed to sadden too brilliant tints or give darker tints of blues, greens, etc., than can be got by these dyes alone. The paste form of carbon black is much to be preferred to the dry condition. The latter has an oily and fluffy character, which prevents it from mixing well with paper stock, resulting in specks and streaks appearing in the paper after it has passed through the presses and calenders of the machine.

Ochres and Earth Colours.—This is a very extensive class of mineral colours ranging from a light yellow to a dull brown or red. They owe their tints mainly to the presence of iron oxides. Many are of natural origin, others are produced by burning or calcining various earths, ochres and clays. They are all heavy colours, practically permanent, and act as fillers more than dyes.

Nitrate of Iron or Iron Liquor is a chemical combination of iron and nitric acid. It acts on fibrous materials to produce a brownish-yellow tint. Used

with ultramarine blue, it turns the latter to a greenish shade and reduces the brightness of too brilliant colours. The yellow shade is permanent and tends to deepen with age. It is very valuable for toning down mixed furnishes, as it acts on most fibres equally well, and does not produce the mottled appearance which is caused by toning with aniline yellow.

Carmine or Cochineal Paste is the only colour of its kind, being made from the bodies of cochineal insects, which are parasites of the prickly pear. While not so powerful as the brilliant pinks of the aniline class, it is peculiarly adapted for dyeing high-class papers, owing to the ease of its manipulation and its purity. It requires to be treated with ammonia and cream of tartar (12 lb. of paste, 2½ pints of liquid ammonia, 2 oz. of cream of tartar), and allowed to stand for a week or two to mature. It is very fugitive and is seldom used alone, being chiefly of value in combination with ultramarine for shades of white, high-class papers.

Aniline Colours

These are produced by intricate chemical processes from coal tar in practically every colour and shade. They are of acid, basic or neutral character, but all are fairly easy to manipulate and are fixed by alum. They are absorbed by the fibres, but are mostly very fugitive and susceptible to light. They require to be dissolved in very hot water, and carefully strained to prevent specks of undissolved colour showing in the paper. When combinations of aniline colours are used, acid and basic colours will precipitate each other in the fibres and help to reduce the waste in the back water. They are used for very brilliant shades, alone and with natural colours. They dye mechanical pulp very well and more cheaply than mineral dyes. They are very useful for blottings and other special papers where alum is inadmissible.

Within the last few years some very permanent dyes of this type have been discovered, and it seems likely that in course of time the old-fashioned mineral colours will be superseded by the modern products. It is hardly necessary to give any list of aniline dyes. The leading manufacturers will supply catalogues of their products and send samples for trial; also, they will, on request, match a sample and supply all particulars as to quantities and treatment.

Practical Notes on the Use of Aniline Dyes

Before fibrous materials can be effectively and economically coloured with synthetic dyes, the nature of the fibres and dyes has to be considered in relation to their suitability. Certain dyes are said to have an affinity for certain fibres,

as, for instance, basic dyes for mechanical pulp and unbleached chemical wood. This affinity has not been explained, but it seems to us that the state of the electrical charges in the materials may have more influence than is generally supposed, and a study of dyes and fibres in this light might be productive of illuminating results.

Basic dyes are less fast to light, but have greater colouring power than acid dyes. They should be put into the beater before the alum and size, as they are sensitive to alum. This latter should be used with care, no more than is absolutely necessary for sizing being put in the beater. Where the water is very hard, a small proportion of alum put into the beater before the dye is added will protect the colour in some measure from the lime salts. No other mordant is required.

Basic dyes are most suitable for soft-sized papers of cheap quality, such as S/C tinted printings with furnishes of unbleached strong sulphite and mechanical pulps, but may be effectively used on all papers of low quality.

Where a mixture of dyes is necessary, they should be carefully chosen so that basic and acid are well balanced. Basic dye is first added, then the acid, and no alum or size until the beater has made a good mixture. Half the usual alum is then put in and, after a few minutes' run, the rest of the alum and size. With acid dyes alone the same practice should be followed, but if possible the size should be put in with sufficient time to be thoroughly mixed before the stuff is let down to the machine.

Acid dyes are best held by hard-sized papers, with a slight excess of alum. A good white-coloured china clay greatly assists in brightening both kinds of dye. Soft water just under boiling point (190° to 195° F.) is most suitable and safest for dissolving aniline dyes, with the exception of auramine, with which water at about 140° F. should be used.

It is a bad practice to throw the dye into the beater in a dry condition, though this is too often done to save the time and trouble of dissolving it. Also it should not be put in altogether, but be spread round the vat or run in slowly before the roll, otherwise there are undissolved specks of dye in the finished paper and often mottled fibres caused by the concentrated dye falling on the fibres.

Direct dyes, which are neither acid nor basic, dye the fibres without any mordant. They are much more light-resisting than the other aniline colours, but do not work well with mechanical or unbleached fibres. They are chiefly used for better-class papers, for the production of 'mottled' papers, and for coloured fibres for blottings. Sodium sulphate is the most suitable fixing agent for use with unsized papers, the usual alum and size being sufficient to fix them in other classes.

All fibres for mottling should be dyed with direct dyes and well fixed with sodium sulphate or common salt. After the mixture is complete, the surplus colour should be washed out and the pulp well sized with resin size. The coloured fibres can then be put in the beater in time to mix before the stuff is let down to the machine.

CHAPTER XI

THE FOURDRINIER MACHINE

THE modern paper-making machine is a very complicated affair. We will not in this chapter go into the subject of any specially built machine, such as the huge machines that are designed to make newsprint at 1500 feet or more per minute (see Chapter XVI). We will confine our remarks to the usual type of Fourdrinier capable of making a wide range of papers, from wood pulp alone, wood pulp and rags, wood pulp and esparto, or those fibres in any combination (*cf.* Fig. 37).

The machine actually begins at the stuff chest. These are constructed in sizes varying according to the output of the beaters and the machine itself. For a general purpose machine, say 92 inches wide, and running the above furnishes at speeds up to 150 feet per minute, a chest holding 1½ tons of stuff (dry weight) is a very convenient size. Two such chests will be necessary. They should be set so that the bottoms are well above flood level. The waste valves will then be safe from being dislodged by pressure from outside, and it will be possible to wash out at all seasons of the year. Their dimensions may be such as are most convenient—deep and narrow, or shallow and wide, but the latter are best.

The bottoms should be concave, with all edges bevelled, the pipe to the stuff pump connected to the lowest part, and the waste valve in a similar position. This ensures that, when a chest is to be emptied and washed out, no stuff will be left where the pump cannot get it. It is very important that the last pound of stuff be taken up and over the machine. Where there are many changes of colour, etc., a very great loss may easily occur if this point is neglected. Both chests ought to be lined with glazed tiles, but copper or well-glazed cement will do very well. A connecting pipe and valve between the two chests are very useful. When the machine is stopped longer than usual for any reason, both chests may be filled with stuff and circulated by the pump through the connecting pipe, thus ensuring a large quantity of stuff of the same consistency and shade. Where the chests are capable of containing not less than 1 ton of stuff, the best plan is to run from one while the beaters are filling the other. Then shade, weight, etc., remain constant while the whole quantity

in the chest is being made. The pump and overflow may then be changed over to the second chest.

Some of the older mills are compelled to work the stuff as it is put down from the beaters, owing to their chests being too small to hold a reasonable quantity. Then colour, consistency, and quality of the beating may change with each beater. This occasions a great deal of trouble with 'shades' and 'weights' in a making, as all these may alter several times in one shift. Where a refining engine is used, the chest from which it works ought to be about 30 cwt. capacity and kept well filled with stuff. Then, as the beaters are put down, the change in colour, etc., if it does happen, does so gradually, and the machineman and colourman can make correction before it gets far off the sample. In the same way, if a machine is provided with chests that are too small, by emptying the stuff into one and letting it come gradually through the connecting pipe to the other from which the stuff is being worked, the chance of differences is somewhat lessened.

But it is the worst policy for a mill making 'fine' papers from rags and mixed furnishes to have to do this, for no matter how skilled the beaterman may be, irregularities in makings (weight and especially shades) must always follow. Also, as no two beatermen treat their stuff in the same degree as to length, wetness, and even the quantity of water they let down with the beaters, there are bound to be at least three upsets in the colour, make, and weight every 24 hours. Where two chests are used alternately, it is possible to get more strength from a mixed furnish; for instance, a paper made from ¼ strong canvas, ¼ cotton seconds, ¼ wood, ¼ broke, and intended for a water-marked bank, about 13 lb. Large Post substance.

By putting these fibres into separate beaters, the utmost value in length and wetness may be got from each. But if they have to be beaten together in one beater before the strong canvas is milled and properly cleared, the other and softer fibres will be reduced far below their greatest possible strength.

Agitators.—There are two types of agitators or stirrers used in chests. The old type is a gate-shaped contrivance with cross and diagonal bars, which simply stirs or mixes the stuff by travelling round. The newer and more efficient is composed of two blades, preferably copper-covered, shaped like the propellers of a ship and fixed to a driven shaft near the bottom of the chest. The circulation and movement of the stuff may be observed when colour is added. Put in at the side of the chest, it travels round in a spiral streak until it reaches the centre, when it is seen to disappear downwards. Therefore, besides the travel of the stuff *round* the chest, it is being thrown *up* from the centre bottom to the top sides, and from there round, inwards, and down to

the bottom again. It is very important that, where esparto fibre is used, the agitators should be run slowly, otherwise the fibre will be rolled into little knots or balls. As efficient stirring is absolutely essential for the mixing of colour, loading, etc., it may be necessary to have two additional wings or blades half-way up the centre shaft to keep a full chest properly mixed. The top of the chests should be covered and made water-tight, leaving only a manhole with a properly fitted lid or cover. Generally, the agitator shaft is driven by bevel wheels on the top, and proper precautions must be taken to prevent grease, oil or dirty water from finding their way down the shaft or through the opening left for the shaft. This may be accomplished by having a disc of metal running over the opening. Another, shaped like an inverted umbrella, may be bolted on the shaft close inside the top and cleaned out every time an opportunity occurs. Though a rinse out with the hose-pipe is sufficient in washing out a chest on most occasions, all chests should be thoroughly cleaned and brushed at every opportunity.

On a change from blues or colours to white, this is compulsory. Where the water is hard, it will be found that limy 'scale' will form on the side walls and blades of the agitators. Soft water is productive of 'slime'. The machineman should always satisfy himself that his assistant has cleaned the chest properly before allowing the stuff to be emptied into it. The beaterman should see that the waste valve has been replaced, and when a chest is to be cleaned he may take the opportunity of flushing out his stuff pipes with a copious rush of water. Complete co-operation between the machineman and the beaterman is essential, if mistakes are to be avoided, in the matter of waste valves, changing pump from one chest to another and having the overflow running into the correct chest.

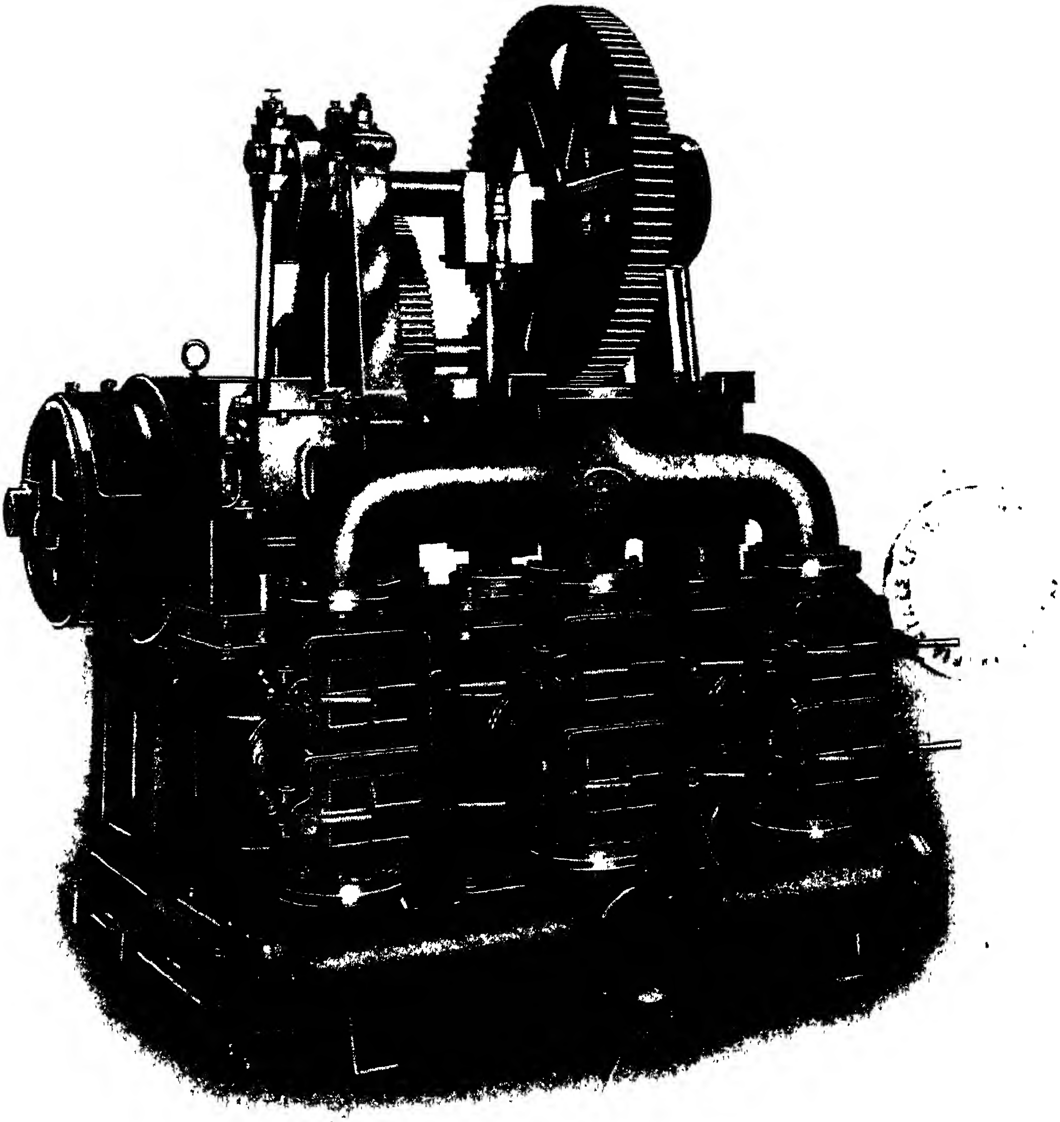
Portable lights should be provided for covered chests, to allow of proper observation of the quantity of stuff and for efficient cleaning.

The Stuff Pump (Fig. 38).—There are two kinds of stuff pumps in use—the ordinary plunger pump with lifting valves, and the centrifugal pump. A badly fitting or dry plunger or barrel will roll up the fibres, and for this reason it is necessary to have a jet of water constantly playing on the barrel and washing off the little bits of fibre that may come up with each lift.

The centrifugal pump has none of these faults. Indeed, the action of the swiftly moving blades has a certain 'clearing' effect on knotty or badly cleared stuff. There are no leather or other moving valves to get out of order. By regulating the chest pipe-gate, it may be made to supply more or less as desired, and to keep a good level in the stuff box as the level of the stuff in the chest goes down. Driven by one belt, it occupies very little space, and its simple construction ensures cleanliness and few breakdowns. A glance at the

driving belt occasionally, however, may save the machineman an unexpected shut.

The pipes leading from the chests to the stuff pump, and thence to the high-level stuff box, do not, as a rule, get very dirty, but a scrub out once in six



[*Bertrams Ltd.*

FIG. 38.—THE PLUNGER TYPE STUFF PUMP, DIRECT DRIVEN BY ELECTRIC MOTOR

months is necessary to get rid of bits of metal, buttons, chips from the bars of the beater plates, etc., which collect in the lower levels.

The Stuff Box.—This should be situated where it can easily be got at for cleaning purposes, and in such a position that the machineman can reach it in

the shortest possible time, as it is often necessary to shut off stuff in a hurry. Sometimes a pipe is led from the stuff box to a convenient position, and the stuff gate made more accessible, but this entails another pipe to clean, or another source of scale and slime. Very often very large, elaborate stuff boxes are provided, but all that is really required is a box about 3 feet deep and 3 feet wide, tile- or copper-lined. Larger than this means waste of stuff when running out or changing colours.

The overflow from the box should be wide, so that there will not be a great change in the level of the stuff with the possible variations of the stuff pump. The overflow shute runs to the chests, with a slide or gate to direct the stuff to either chest. The whole box and overflow pipes or shutes need very frequent cleaning. The waste valve of the stuff box should be replaced carefully and examined by the machineman before he starts to pump up stuff. A problem which confronts the machineman is how he can deal with the stuff in the box when it is left from Saturday to Monday. The stuff left in the box may be found to have lost its water by leakage through the stuff gate. He must then either lift it out or risk having the overflow block up by pumping up fresh stuff. On the other hand, if the stuff gate is quite watertight, the thick stuff will lie on the bottom of the box and may block the valve after he has started up the machine.

If the stuff pump has a loose pulley he may stop the pump and let the stuff run out of the box. If not, he risks broken valves if he shuts the chest valves to stop the supply of stuff. To empty the box after the machine has been shut down means wasting valuable material.

With a centrifugal pump the chest valve may be shut without risk of any damage, but in both cases there still remains the contents of the pipe from the pump to the stuff box. This shoots up, on starting again, in a thick column and makes a mess all over the place.

The best way out of the difficulty is to try to run a chest empty when shutting down on Saturday. The hose-pipe may then be run into the chest, or the beaterman may put down a flush of water and clear the stuff through the pipe and pump, and run it over the machine. In any case, when running out a chest and changing colours, when it is necessary to shut and wash up, the pipes, pump, stuff box, etc., should always be emptied and all the fibre possible run over the wire. The fibre recovered in this way may be run up the press rolls and taken back to the beating room. A very valuable help is a water connection between the chest valve and the stuff pump; the valve may be shut and the water run into the pipe, thus driving the stuff in front of it to the stuff box.

The Stuff Gate.—This important valve is not apparently considered worthy

of much attention by the engineers who fit up our machines. It is too often just a valve opened by a rough-threaded screw and without any gauge attached for the machineman's guidance. Those men who run machines making fine papers, where there are many changes, would appreciate a valve opened by a micrometer screw, with a good gauge, showing clearly the difference made by the slightest alteration. A record of makings can then be kept by the machineman with the approximate readings of the stuff-gate gauge. This, of course, will not give the correct position for weight, speed, breadth, etc., from one making to the next, but if carefully kept will be of very great assistance in giving the machineman a good idea of what he may put on for a start. As no machine is immune from stoppage through foreign substances or clumps of uncleaned fibres coming through, or not coming through, the opening of the stuff gate, provision should be made for a quick and full opening to clear away the obstruction.

It is important that the stuff gate should always be worked as wide as possible to lessen this risk. Thin papers, of course, require a small opening, but the beaterman and machineman should have a settled consistency for thick and thin papers worked in conjunction with a written record. In this way a paper that normally would require a small opening would be put down with more water from the beaters and the stuff cock could then be further opened up. The very little trouble required to keep a record of stuff-gate opening is very amply repaid by the smarter working of the machine, quicker and more accurate changing of sorts, and less broke. Where two chests of the same size are worked, the consistency of the stuff, which just means weight per ream, may be kept practically constant by careful filling to the same level. Various devices have been tried, worked by the density or consistency of the stuff, for regulating the stuff gate and keeping steady weight. But this is one of the many points in paper-making where human skill cannot be replaced entirely by automatic means. While several firms have produced many types of consistency regulators, none of these has proved entirely satisfactory for all kinds of paper. The very fact that there are so many varieties of these regulators on the market, and that new ones are always coming out, seems to confirm this. A point that is worth noting is that fine stuff requires less opening than strong stuff for the same weight per ream, and heavily loaded stuff less than unloaded.

It is remarkable that remote controls for stuff and water gates are not standard equipment in every paper-mill.

As these gates are usually in an elevated position by the head box, much time and effort is wasted by the machineman when making changes. When it is considered that until he makes an adjustment, the paper may be the wrong

weight, or otherwise badly made, with too much or too little water, the small expenditure involved in fitting controls which operate at the front of the wire is soon recovered.

The 'Back-water' System (Fig. 39).—The 'back-water' system is composed of the following main parts: A centrifugal *water pump* to raise the water to the *high-level water box*. A *low-level water box* to collect the water from the

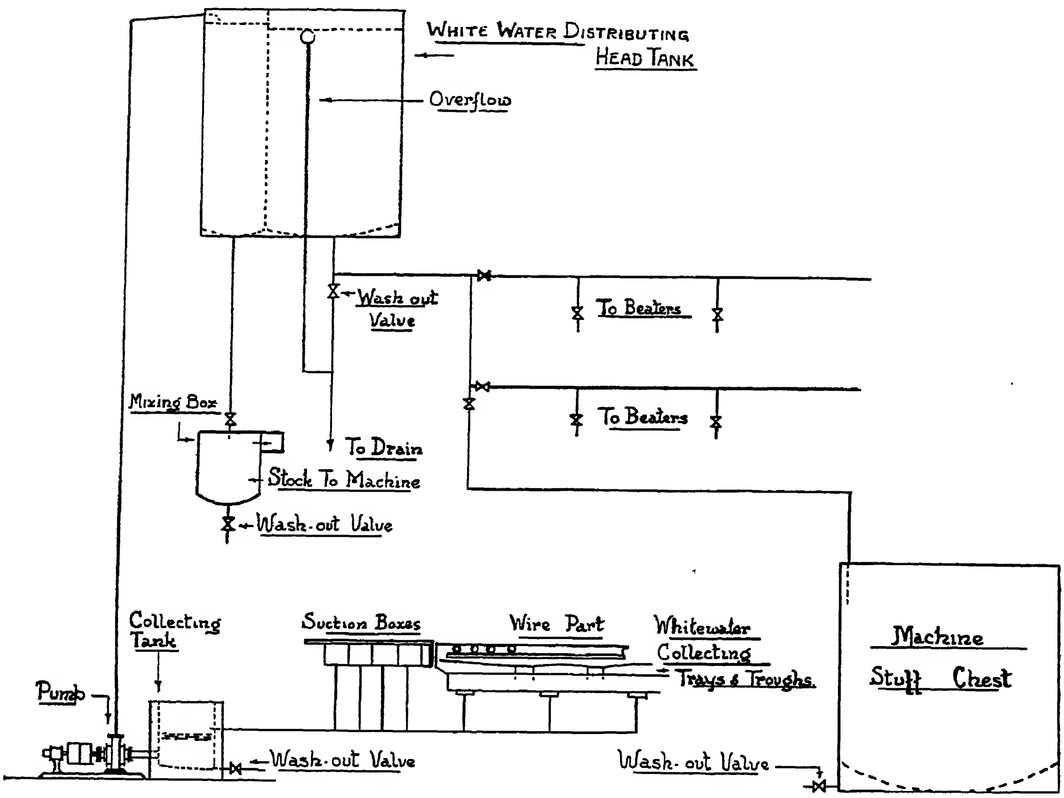


FIG. 39.—A BACK-WATER SYSTEM OF A PAPER MACHINE

In this diagram are shown the essential parts of a back-water system of a paper machine. All water collected at the wet end is pumped up to a distributing head tank, which is divided off by a partition. The whitewater from the smallest compartment returns to the mixing box, and keeps the machine supplied constantly. Any excess overflows into the large compartment of the head tank, and is distributed as shown in the diagram.

save-all trays under the wire, and from which the pump draws its main supply. Suitable *water gate* on the high-level water box to regulate the supply of water to the stuff going over the machine. Overflow pipes at a certain level on high- and low-level boxes. A better idea of the water system may be gathered if it is described in action. The fresh water is turned on full to obtain a head of water sufficient for the working of the stuff until its place can be taken by back water. The water gate and stuff gate are then opened to the estimated extent

and the mixture of stuff and water is run to the wire. As soon as the wire is moving, and the water begins to drain through it and fill up the low-level box through the save-all trays and shutes, the fresh water may be partly shut off. Sufficient overflow is left for a few minutes to compensate for any change the machineman may make. As soon as he has got the correct proportion of the stuff and water, the water valve may be closed, so as to leave little more than the surface froth going down the overflow from the high-level box. This will have the effect of overflowing the low-level box, and the fresh water may be turned off to reduce the overflow in the same way. If the adjustments are correctly made, it will be found that no fresh water will be required.

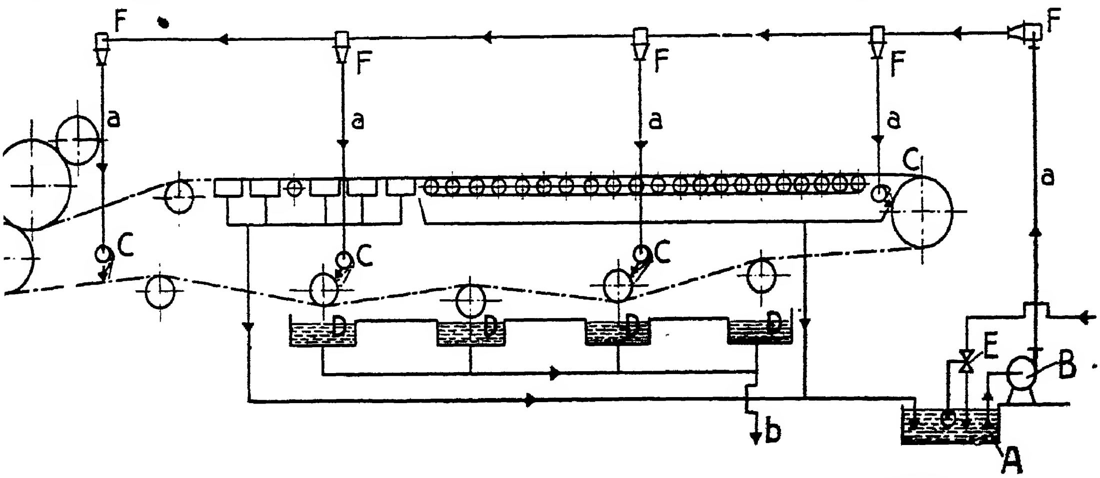


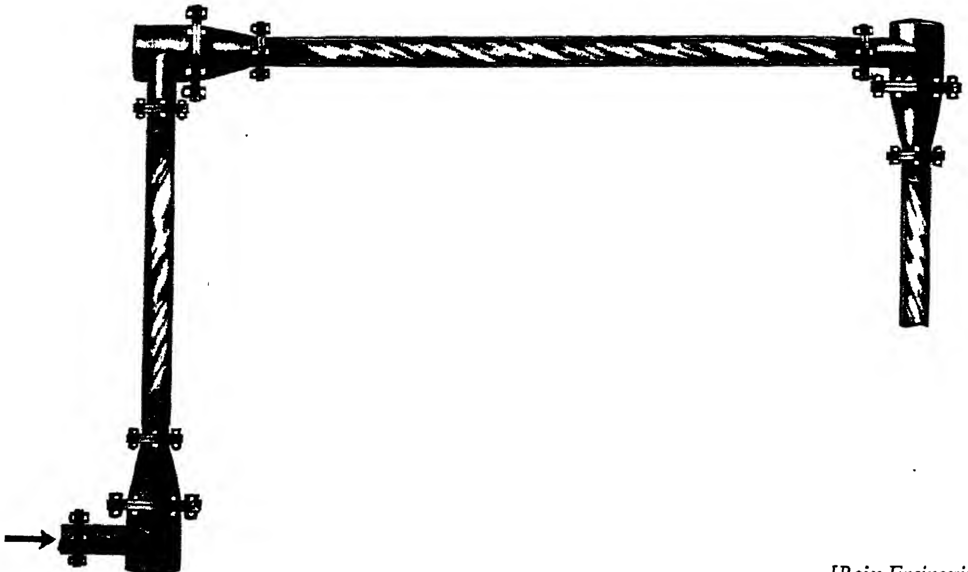
FIG. 40.—THE ROTOR WHITEWATER CIRCULATION SYSTEM [*Reiss Engineering Co.*

The whitewater from the save-all tray and the back-water from the suction boxes are both collected in pit 'A'. By means of pump 'B' this water is conducted through the supply pipes 'a' to the Rotors 'C', and is used as spray water. The trays 'D' collect this whitewater again and conduct it through the supply pipes 'b' to the existing pump for diluting the stuff in the mixing box. Fresh water, which is necessary during the starting of the machine, is automatically added by the floating valve 'E'. 'F' is the turbine which causes the water to spin.

The back water will gradually attain to its full saturation of size, loading, colour, etc., and the stuff coming from the chest will get all the benefit of these things returned over and over again. It is an advantage to have a connection from the suction pump which deals with the suction boxes. The fine fibres, loadings, starch, colour, etc., may then be led back to the low-level box and any overflow pumped to a tank in the beater room to be used in furnishing the beaters. Some 'fine' mills, however, prefer to lose the suction-box water rather than risk having in the paper dirt and bits from the suction-box packing. Still, as the machine may have a run of engine-sized or printing paper, these otherwise wasted materials could be used.

Rotor Whitewater Circulation System (Fig. 40).—A new method of recovering fibre and loading from excess whitewater has recently been introduced, and quite a large number of the plants have been installed on paper machines.

Obviously the ideal conditions for a mill would be to work with a system whereby no excess whitewater would accrue. The flow diagram shown on p. 143 indicates where the water enters the system at the wet end. By using a closed whitewater system it is possible in many cases to eliminate almost entirely the use of fresh water. The whitewater flow diagram shows the scheme of a closed whitewater system, where whitewater is used for cleaning the strainers, killing froth, and for cleaning the wire. The use of whitewater for



[*Reiss Engineering Co.*

FIG. 41.—SPECIAL BENDS AND PIPES OF ROTOR WHITEWATER CIRCULATION SYSTEM, TO CAUSE THE WATER TO SPIN THROUGH THE PIPES SPIRALLY, AND THUS KEEP THE DISCHARGE OPENING CLEAR

this purpose makes it necessary to find special devices, which are needed to do all this work with the same efficiency as if fresh water were used. This system, which has been developed successfully, is known as the British Rotor Whitewater Circulation Plant, and it makes it possible to utilise whitewater from the save-all trays and suction boxes—before it is used for diluting the stuff—for cleaning the strainer, killing froth, and cleaning the wire.

The principal object of this plant is to prevent the accumulation of fibre and loading in the pipes, and also to avoid choking the holes in spray-pipes, and further to prevent the fine fragments of fibre and loading which have passed through the meshes of the wire and are floating suspended in water from clustering together. This object is achieved by installing circular bends in the piping, which give a strong spinning or spiral motion to the water in the pipes, which keeps all the fibre and loading in suspension; Fig. 41 shows this device. The spray-pipes are of a similar construction, and have at each end devices which create this spiral motion. The advantages which will

be derived from a completely closed whitewater system are obvious, and, in fact, all mills have always strived to achieve this end, which is so intimately bound up with the very important saving of fresh water and the elimination of effluent which may have to flow eventually into rivers.

If steam has to be used to heat the stuff for heavy or wet beaten papers, the high-level water box is where it will give the most economical and efficient results. The pipes of the water system, and indeed all pipes conveying back water and stuff, must be copper with brass or copper bolts and nuts throughout. The back-water pipes should be taken apart and thoroughly scoured out frequently. A tight bundle of strips of old machine wire pulled through by a good strong rope makes a very efficient scrubber.

The water system of a machine should never be allowed to get dry. If this happens during a shut down, or over the week-end, a quantity of scale or slime is sure to break away when the water is put on, and may continue to come through and get into the paper for hours. The pipes should be left full, with a trickle coming through the water gate and a little overflowing. It will be found, in many mills, that the pipes are allowed to go uncleaned for months, in order to save the few hours this takes, or the few shillings paid for overtime to the fitters who take down and replace the pipes. This is the worst possible mistake, for a machine cannot produce clean paper if the water system is neglected.

From now onwards we must deal with the stuff and water mixed in paper-making proportion, which may be from ½ to 2 parts of stuff to 100 parts of water.

The Sand Traps.—These are the wooden shutes through which the stuff and water flow, leaving in their passage all heavy foreign matter, such as sand, specks of metal, etc., and any substances heavier than fibre.

A difference of opinion exists as to whether deep, narrow shutes, or wide, shallow shutes are most efficient. It is contended by some that deep, slow-moving stuff gives the best chance for, say, a piece of metal to fall to the bottom. Others say that the stream must be shallow and ripply to break up the clusters of fibres and allow the piece of metal to drop. The truth may be with both views, but there seems to be no reason why shutes should not be made with a deep channel in one part and wide and shallow in the other. There ought to be several depressions in the bottom of the shutes at intervals about 3 or 4 inches deep, in which dirt, metal, etc., may be trapped, otherwise it will gradually travel to the end of the shutes and get into the strainers.

It is a very good plan to have the bottoms covered with strips of old wet felt with a good nap and of a handy length to facilitate washing. These are held down by strips or bars of lead. Two sets of strips should be available,

of which one set is kept clean and ready to replace the other. This will save a few minutes' time when washing out. The 'hairy' surface of the felt is very effective in holding back sand and all solid particles. Sometimes 'ladders' are laid in the bottoms of shutes. They are not much good and generally become sources of dirt through neglect. Some mills, making fine papers, have installed electro-magnets in their sand traps.

These magnets attract and retain all particles of iron, and even rust, so effectively that the rusty specks and spots so often seen in tub-sized papers are entirely eliminated. Strangely enough, specks of all kinds of metal seem to be attracted and stick about the poles of the magnet. A good substitute for this machine can be made by magnetising a number of old files and arranging them on the bottom of the shutes. Though not by any means so powerful as the electro-magnet, these magnestised files help to do their bit in giving clean paper.

The sand traps may be utilised to catch a little of the paper-maker's worst enemy—rubber. A board or boards fixed with their under edges just below the level of the stuff, across the shutes, retain a great deal of scum or froth in which may be found specks of rubber that have floated to the surface. If these boards are inclined at an angle away from the flow of the stuff, floating particles of all kinds will be washed up and stranded on their sloping surfaces.

It is generally agreed that the longer the shutes the more chance has the stuff to get rid of dirt, but there is a limit which must be set for economical reasons. Where very frequent changes of sorts are necessary, long shutes may be wasteful both in stuff and time, since every alteration of stuff or water alters the level of the stuff flow, and may even cause the dirt to be disturbed and begin to come through with the stuff. When this happens, the only cure is to shut and wash out the sand traps. The best plan for the machine is to have about 50 yards of shutes, with a by-pass at 25 yards, and a short cut for very thick or wet beaten papers. Banks and all thin papers may be run with the full length, as they have proportionately a heavy flow of water with the stuff. Medium weights and small orders may be run the 25 yards, and those papers which must be run with very little water take the shortest way. If it is attempted to run the latter class through too long shutes, the flow will be sluggish, and most probably will follow a narrow channel in the centre, leaving thick stuff stagnant at the sides. In connection with this, it may be mentioned that when the machineman opens the water gate to run more water with the stuff, the weight of the sheet increases for a few minutes, owing to the slight flooding effect driving the stuff in front of it. Conversely, if he shuts off water, the weight falls temporarily, owing to the checking of the flow. It is, therefore, important that the machineman should keep accurate note of the

time he makes the change and be prepared for the results, which, unless understood, may mislead him into altering his stuff gate. The best method for keeping in touch with the weight is to follow the change by altering the driving speed.

At one time it was considered necessary to have an elaborate 'mixing box' where the stuff and water emerge from their respective gates. This opinion still persists, but many machines have none, and never experience any difficulty from their absence. The best mixing may be obtained by causing the water to strike the flow of stuff as it leaves the stuff gate at right angles on an inclined plane, or the water may be made to fall on it from above. The force of the water effectually breaks clumps of fibres and carries them well mixed into the shutes. Any good that a mixing box may accomplish in the way of retaining sand or metal is counterbalanced by the fact that it is usually under the level of the shutes, and in an awkward position for being cleaned. Also it has to be emptied, and this means losing stuff. The shutes should have a fall of about 2 feet into the strainers, and this will be ample for mixing the fibres and water.

[*Blackfriars Engineering Co.*

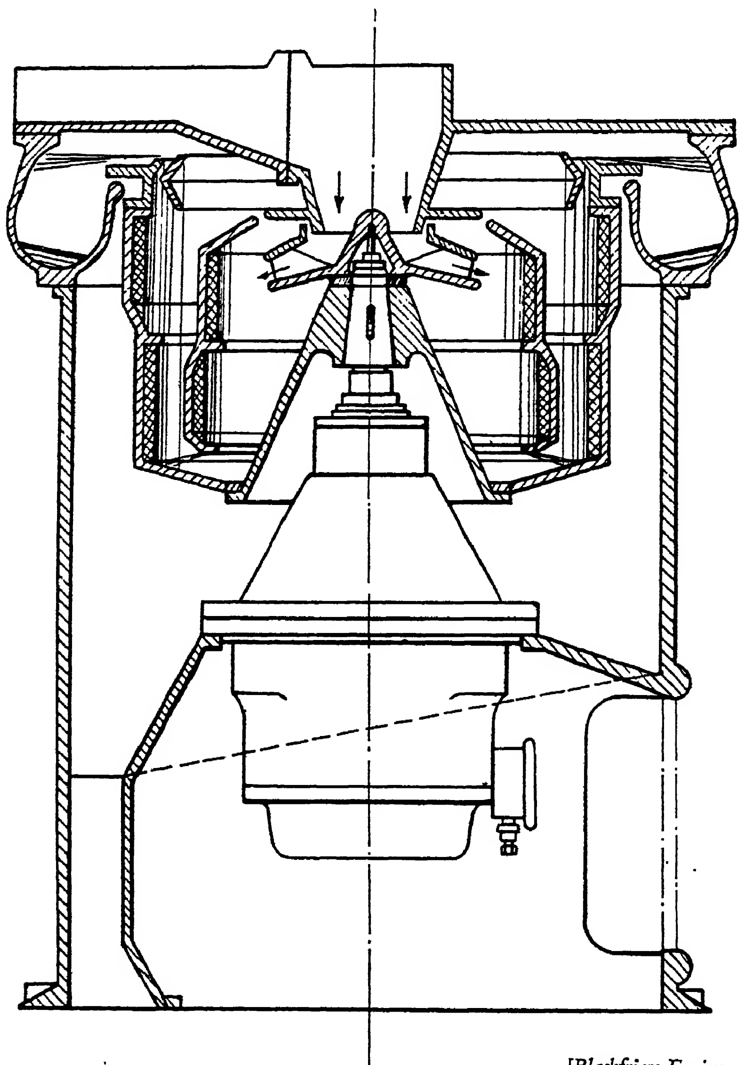
FIG. 42.—THE ERKENSATOR, SIZE IV, SHOWING LID OPENED FOR CLEANING, AND REVEALING THE INNER CYLINDERS

CENTRIFUGAL CLEANING MACHINES

Most mills nowadays which make fine papers rely almost entirely for the cleaning of their stock and the freeing of it from foreign matter such as metal, sand, shive, rubber, etc., on centrifugal machines, such as the Erkensator, which was the first of these machines. These machines depend for their efficiency on the action of centrifugal force. The fact that cellulose, water, and to a less extent loadings in general, have specific gravities sufficiently near to each other, enables these to pass through the machine together, while heavier and lighter substances are retained behind projecting rings, or in the case of lighter particles are removed by skimmers.

The machine (Fig. 42) consists of the following parts: An outer container with lids for access, and a trough running right round the top for receiving the

clean stock. Inside, a series of phosphor bronze cylinders or rings, which fit one inside the other, and are driven by a motor from underneath. The stuff is led over the centre of the machine and pours down to the bottom of the inner container. The whole of the inner vessel is revolving at a very high speed,



[*Blackfriars Engineering Co.*

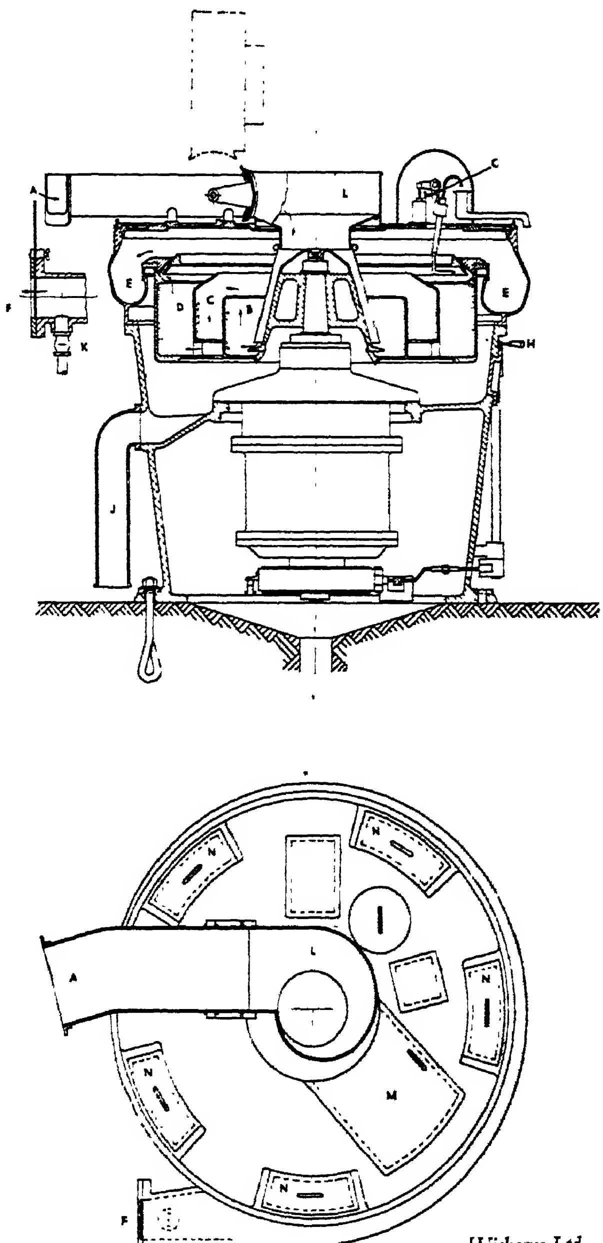
FIG. 43.—DIAGRAM OF THE ERKENSATOR, SIZE IV, SHOWING THE PATH OF THE STUFF AS IT PASSES THROUGH

The shaded portion represents the foreign matter trapped behind the collecting rings

so that the stuff when it reaches the bottom is immediately flung out in all directions against the inner wall of the innermost cylinder. The spinning action causes the stuff to drop to the bottom of the ring, where it meets with the opposition of a lip or ring, over which it has to pass. Behind this first lip the heaviest particles are trapped, because their specific gravity is so great that

they are unable to overcome the action of the centrifugal force, and climb inwards over the lip. The water and lighter cellulose fibres pass this lip, and are immediately flung out further into another ring, up which they travel on account of the pressure behind them, until they meet another projecting lip half-way up the second ring. Here other impurities, less heavy than those retained at the first lip, are trapped, and the fibres and water, passing over the lip, are flung out still further into a third ring of still greater diameter. They proceed to climb up the inner wall of the third ring, where they meet yet another projecting lip, and it is in this ring where most of the shive is caught. By the time the fibres and water have reached the end of this third ring they are practically entirely free from all foreign matter which is of a higher specific gravity than cellulose.

At this point it is possible to remove lighter things, such as rubber, cork, etc. This is done by causing the nozzle of the skimmer to plough the inner surface of the water and fibre just as it is passing out of the final ring on its way to the collecting trough of the machine. This top skimming contains, of course, valuable fibre, and it is at once led into an auxiliary strainer, where the impurities are separated out of the stock, which then goes back to the mixing-box chest or back-water supply service.



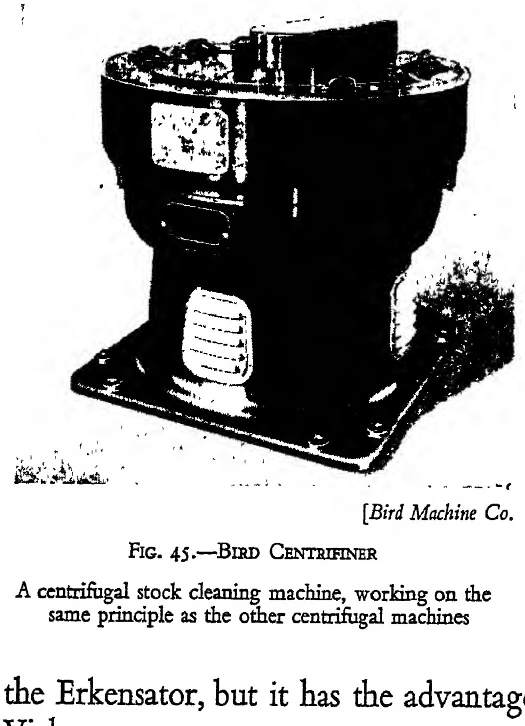
[Vickerys Ltd.

FIG. 44.—VERTICAL ELEVATION AND PLAN OF THE PURIFUGE CENTRIFUGAL STOCK CLEANING MACHINE

This machine has three internal cylinders, and is very accessible for cleaning

It is often argued that these centrifugal machines are wasteful of stuff, but when it is remembered that these machines need to be cleaned out, say, only once every 12 hours, and in many cases at much less frequent periods, it will be seen that the loss is negligible, and that the greatest portion of the loss consists, in any case, of impurities.

Against this loss also must be considered the fact that the paper can be guaranteed to be absolutely clean and free from specks, and that it is also no longer necessary in, for instance, the case of a rag mill to employ any sorters to sort the rags in search of buttons, metal fasteners, pins, etc. The rags, in fact, unless they have to be sorted to remove certain qualities, can be passed straight from the bale into the chopping machine, and all the subsequent removal of impurities may safely be left to the Erkensator.



[*Bird Machine Co.*

FIG. 45.—BIRD CENTRIFINER

A centrifugal stock cleaning machine, working on the same principle as the other centrifugal machines

To get the best results from these machines, it is necessary that stock passing through them should be very dilute; in the case of wood pulp, densities should not be greater than 0.75 per cent, and for rag stuff about 0.5 per cent or less. At these consistencies the machine will remove practically the whole of the shive, which has very little greater specific gravity than the cellulose itself.

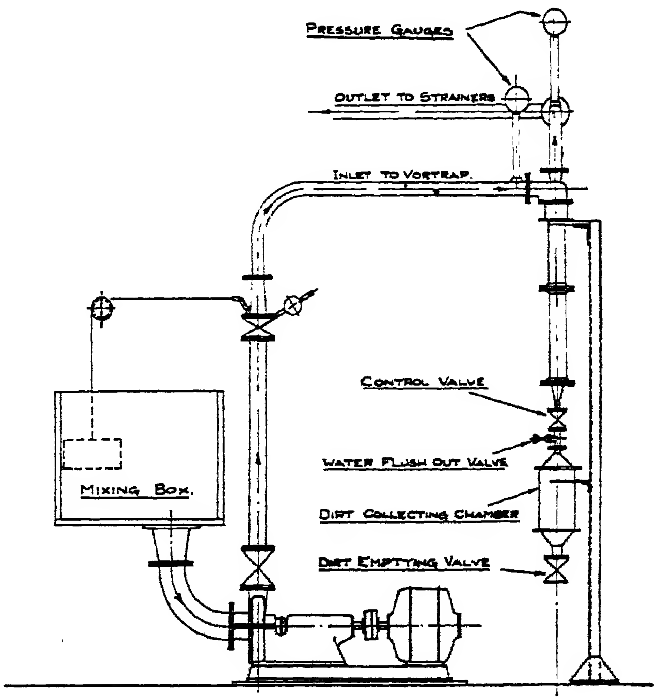
The latest centrifugal machine is the Purifuge (Fig. 44), which works on more or less the same lines as the Erkensator, but it has the advantage that it is made in England by Messrs. Vickerys.

The Bird Centrifiner, which is made by the Bird Machine Company of Canada, is of similar design to the aforementioned centrifugal stock cleaning machines, and has a high capacity.

It is sometimes said that the centrifugal machine removes immediately the heavy loading material, and it must be admitted that it does this immediately it is started up, in order to fill the 'bolster', as the lining inside the rings is called. This only takes a few moments, and after that no more loading is, in fact, removed. In order to get over this difficulty, it used to be common practice to put in a bucketful of loading before the stock was turned on; now, however, it has been found to be much more satisfactory, from every point

of view, to add the loading in a continuous stream after the stuff has passed through the centrifugal machine. The section of the latest type of Erkensator can be seen in Fig. 42, and the path of the stuff can be easily traced through the machine (Fig. 43).

The maintenance costs of these machines are extremely low; there is nothing to go wrong with them, except, perhaps, a bearing, and there are many of



[*Walmsleys (Bury) Ltd.*

FIG. 46.—THE VORTRAP, SHOWING THE COMPLETE ARRANGEMENT AND PATH TAKEN BY THE STUFF

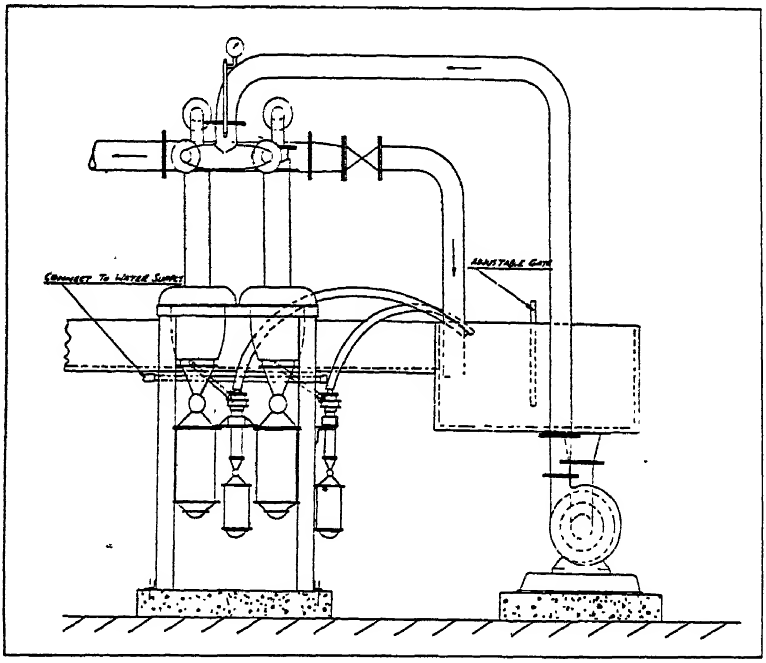
these machines running continuously which have been in operation for 20 years without having broken down, and with no expense for repairs.

THE VORTRAP

The Vortrap (Fig. 46) has been produced with the idea of separating dirt and other impurities from the stock without employing the power and apparatus required in other centrifugal machines. The principle of it depends on centrifugal action. As will be seen in the accompanying drawing, it comprises a vertical cylinder of small diameter divided in sections by perforated partitions. The stuff is injected into the cylinder tangentially, causing it to spin round rather like a vortex. This action throws the heavy particles to the outside of the cylinder, and they rise up to the top where they meet the upper partition. Here they are deflected

downwards through the centre hole of the partition, only clean stock passing upwards along the axis of the cylinder to the trumpet-shaped outlet. The dirt which has passed down the centre falls into the funnel at the bottom and thence into the waste receiver. This waste receiver can be shut off and emptied while the Vortrap is still in operation.

It is claimed for this apparatus that it is very low in first cost compared with other centrifugal machines, and that it separates a large quantity of the dirt usually contained in paper stock.



[*Vickerys Ltd.*

FIG. 47.—DIAGRAMMATIC ARRANGEMENT OF A TWO-UNIT DIRTEC INSTALLATION

The Dirtec (Fig. 47) is a static type separator for the removal of dirt from pulp and paper stock. The machine has no moving parts, the separation being obtained by the employment of the differences in pressure of the stock itself. It is effective and suitable for all except the very highest grade stocks, both heavy and light dirt being removed continuously without stopping for cleaning.

It is, however, still necessary to keep the strainer in use. Froth is produced in great quantities by the excessive aeration in the machines. Coagulation takes place when the stuff has a long distance to travel to the breast box, and creates difficulties in the formation of the sheet on the wire. Knots, small clumps of unseparated fibres, and shives, such as are found in esparto and wood-pulp papers, and which are of the same specific gravity as cellulose fibres, are still to be dealt with. It is therefore inadvisable to run a strainer with a more open cut than is required for getting the stuff freely through, though in some cases the cut may be much more open.

The earlier forms of strainers were flat boxes with perforated metal plates forming the bottom, the perforations being in the form of narrow slits about 2 to 3 inches long. The slits vary in width according to the form of pulp which has to be strained, and the 'cuts', as they are called, are known by numbers, such as '3' cut, or by their width in thousandths of an inch. The cuts are spaced about ¼ inch apart, or far enough to prevent long fibres from getting their ends through two different slits. Flat strainers of a modified and improved type are used extensively in America for straining all kinds of stock, and they still have adherents in this country, especially among paper-makers dealing with strong rag stock. These strainers consist of a flat trough, the bottom of which is formed of the strainer plates with slits. Underneath is another trough, the bottom consisting of a flexible metal diaphragm, attached underneath to rods which in turn are in contact with cams on a rapidly revolving shaft. These cams lift and drop the rods, and this causes the metal diaphragms to oscillate up and down, thus causing an alternate sucking action through the strainer plates, causing a partial vacuum on the downward stroke and a reflex action on the upward stroke.

The suction downwards draws fibres and water through the slits, but it also causes fibres to be drawn over the narrow slits and so clogs them up. The 'reflex' or upward flow on the upward stroke of the diaphragm pushes them away, mixes them up with water, and some are thus ready to flow through the slits at the next downward movement of the diaphragm.

If there were no 'reflex action', the strainer would quickly become completely clogged up with a coating of stuff, just as in the case of the revolving drum or mould on a 'mould' machine. This 'reflex action' is an essential feature of all strainers, and many different methods are used to promote it.

The slits are always narrowest at the side on which the fibres enter, and they open out towards the opposite side. This prevents them becoming clogged up by congregations of fibres trying to squeeze through.

The passage of the fibres and water through the slits is brought about by two chief causes: First, gravity, or the weight of the water in which the fibres are suspended; secondly, by the sucking action of the diaphragm.

The older type of jog strainers are operated by ratchet wheels, the teeth of which engage and lift rods fixed to arms projecting from the sides of the vat. The opposite side of the vat is hinged, so that the vat moves freely up and down. The action is, therefore, actually a tipping motion. These strainers are still much in evidence, as they are to be found in most mills, being used in conjunction with the more recent revolving strainers as 'back knotters' or auxiliary strainers, to which we shall refer in greater detail later on.

The greatest drawback to the use of these flat strainers is that they are constantly becoming filled up with the coarse stuff, shive, rubber, dirt, etc., which they have prevented from getting through and into the paper.

In order that the strainer will still continue to pass sufficient stuff to keep the weight right at the machine, it is necessary that it should be frequently cleaned and rubbed over by the machineman. This is very unsatisfactory, and it leads to lots of dirt, etc., being let through; it also takes time and interferes with the weight. Various devices have been resorted to in order to make this cleaning automatic and continuous, but none of them is really adequate.

In some forms a trough is provided at the opposite end to that at which the stuff flows on, and in this the coarser and uncleaned stuff collects, along with rubber, and is led away.

There is no doubt that one of the chief necessities which caused the invention of the revolving strainer was the need for automatic cleaning of the plates. In the revolving strainer the plates form the circumference of a skeleton cylinder, which revolves partly submerged in a semicircular cast-iron trough, and is called the drum.

There are two types, the inward and outward flow, and in both the slits or cuts are kept clean with a strong shower of water applied by means of a perforated pipe.

In the case of the 'inward flow' the stuff is led into the trough, and has to pass through the slits into the inside of the drum, and the cuts are cleaned by a shower pipe inside, which forces water upwards through the drum either at the top or at the sides, well away from the stuff in the vat. Some of this water and the fibres which it dislodges are caught in a trough and led away to the auxiliary strainer. The remainder of the water which is not caught and the hanks and knots of fibres fall back into the vat, and those knots which are not broken up sink to the bottom of the vat, and either lie there until cleaned out or pass away with the dirt, etc., to the auxiliary strainer through a tap at the lowest point of the trough.

In the 'outward-flow' strainer the shower is applied from above and outside the drum, and the dirt, knots, etc., fall back into a metal trough placed horizontally along the inside of the drum, and are washed away to the auxiliary strainer.

The inward-flow strainer is superior to the outward-flow, especially for better-class papers, where freedom from dirt and blemishes of all kinds is of the first importance. It is much more easily cleaned, because most of the objectionable stuff never gets into it, but remains outside in the trough.

When the stuff flows in from the sand tables, any heavy dirt, grit or knots

will naturally sink to the bottom, or if they come in low down they will be inclined to stay down. A deep channel is provided in the bottom of the vat in which these things collect, and a cock is usually provided, which can always be kept partly open to allow them to be carried away to the auxiliary strainer.

Further, in some strainers an adjustable sluice is provided at about the normal level of the stuff in the vat, and this can be so raised or lowered as to allow the top scum, in which most of the rubber floats, to run off into the auxiliary strainer. Thus two means are provided for getting rid of some of the various causes of blemishes in the paper.

The principle of working of most of the inward-flow strainers is much the same. The water in which the fibres are suspended flows through the slits to the lower level inside, carrying fibres with it, but in order to prevent a film of waterleaf being formed on the outside of the drum, the reflex action already referred to has to be set up. This is done in one type of strainer by vibrating the flexible drum itself, and so causing waves and ripples to ebb and flow through the slits. More fibres and water will pass through than will be passed back again, owing to gravity and the flow of water to its own level. In the Reinicke and Jaspar, and Banning and Seybold, types of inward-flow strainers the reflex action is caused by the oscillating of flappers, or large perforated plates fixed to a strong shaft. This shaft is placed immediately under the lowest part of the revolving drum, and it moves backwards and forwards, causing the plates to flap like wings in the stuff and send it in waves up against the slits of the drum.

The motion is very effective in passing the stuff through, but the mechanical action is very drastic and, being also erratic, it entails the use of very heavy shafting and strong metal plates, which consume a large amount of power and lubricating oil and cause a good deal of wear.

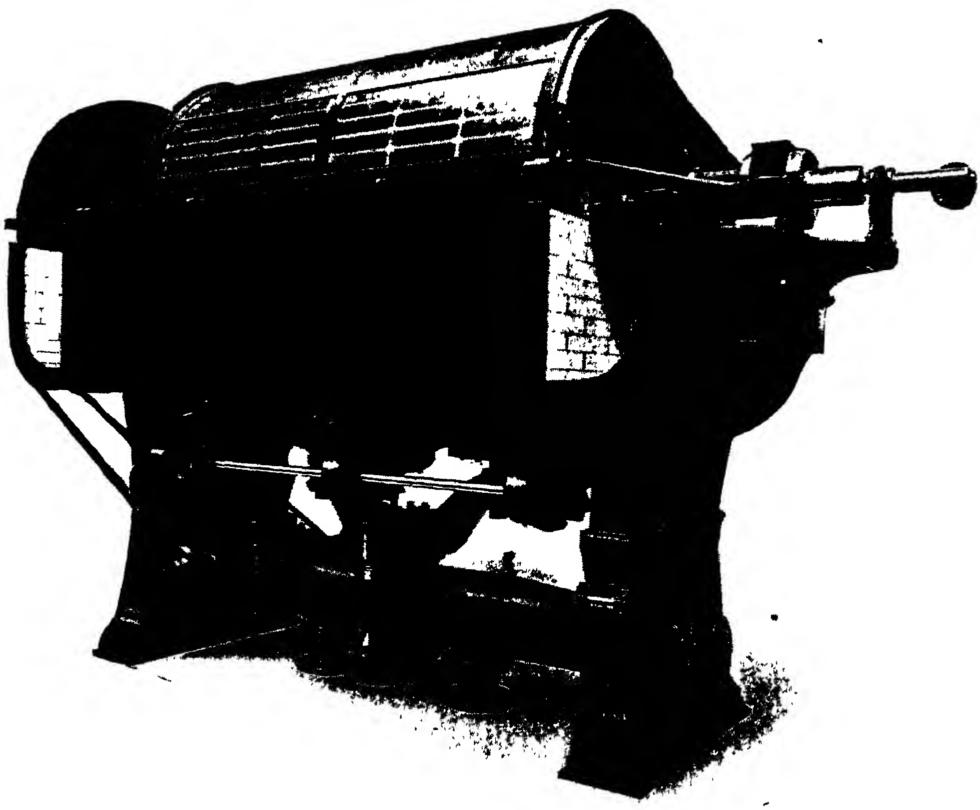
Another excellent type of inward-flow revolving strainer is that made by James Bertram and Sons, and known as the Leith Walk Full-Drum Strainer (Fig. 48). This is the simplest inward-flow strainer we have seen, and it has many advantages to recommend it. It is noiseless, simple in construction, easily maintained and efficient in working. It consists of the usual cast-iron vat lined with glazed tiles, and the drum may be either driven by a ratchet mechanism, to give an intermittent motion, or it may revolve slowly and continuously.

The method used to produce the reflex action, to induce the passage of the stuff, is much the same as that used in the later models of the flat strainer; a vibrating brass diaphragm is situated immediately below the drum, and is actuated by two arms fixed to the vibrator and driven by a completely enclosed driving gear below. The stroke given to the vibrator may be varied at will

while the strainer is working, and the vibrator may be removed from the bottom of the vat without disturbing the drum.

All the driving mechanism is entirely enclosed and works in oil, so that no water can get near it.

The pulp enters the vat below the level of the diaphragm, so that heavy particles and dirt are inclined to stay down in the lowest part of the trough. The stuff is pushed upwards against the lowest part of the drum, and passes



[*James Bertram and Sons Ltd.*

FIG. 48.—THE 'LEITH WALK' FULL-DRUM INWARD-FLOW REVOLVING STRAINER

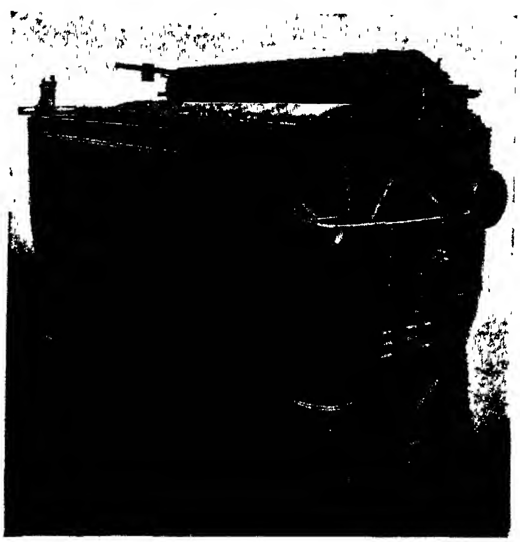
through into the drum, from which it is poured out at the ends into the shute, which takes it to the breast box.

A strong shower of water is played against the slits at the top of the drum to clean it. This strainer is giving universal satisfaction, and possesses distinct advantages over most of the other inward-flow strainers, not the least of which is its freedom from a large collection of exposed working parts, belts, etc.

One of the latest strainers, and one which is giving great satisfaction in mills using short-fibred stock, is the Bird screen (Fig. 49). This is a large inward-flow strainer capable of passing a very large amount of stuff.

The vibrating motion in this strainer is given to the whole vat, the drum revolving without shake, and no vibrating diaphragm being necessary. The body of the vat rests on semicircular brackets which are attached at one end to a spring, like the wire-frame spring support of a Fourdrinier wet end; the other end of the bracket is pivoted to the shake arm, which is actuated by a rod connecting to an eccentric shaft. The moving vat is connected to the fixed parts by a rubber connection.

The stuff runs into the strainer from above and flows against the revolving drum, passing through the slits to the inside and thence out at the ends to the breast box. There is no violent action about the vibrating movement as in the case of the 'Leith Walk' and Banning and Seybold flappers, the shake given to the vat being easy and effective. It is claimed that only 25 per cent of power is required to drive this strainer compared with the diaphragm or vibrating drum type.



[Bird Machine Co. and Vickerys Ltd.

FIG. 49.—LATEST TYPE BIRD SCREEN

The plates are interchangeable. The strainer drum is closed at one end and discharges stuff at the other, and double packing strips are used to make the joint between the drum and vat, to prevent the mixing of screened and unscreened stock. There is a spray pipe at the top, and the water and loosened stuff are caught in a winged trough.

The Box Strainer is a very old, but extremely useful, type, which is capable of dealing with almost any class of fibres. A metal tank is set very firmly on a good solid base. Inside this is a brass rectangular framework, on which are bolted the strainer plates. These may be of any suitable 'cut'. They are arranged in rows of four, sixteen in all, and form an oblong box. This box revolves inside the tank, being connected at the back side through packing glands, with a worm and screw gearing. The front side is open through glands, and connected to a receiving box outside the main tank. A series of rubber diaphragms or 'bellows' is arranged inside the plate holder, and vibrated by a small crank and shaft which passes through the centre of the revolving gear. The first disc or bellows makes the back end of the plate box air- and water-tight. The strainer being set in motion, the stuff is run into the outer tank. The vibration of the diaphragms soon fills the inner box, and the level of the stuff in the receiving box

outside rises until it reaches the desired level, when it is run down to the lowest breast box.

This is an excellent strainer for high-class papers, as the plates are easily changed for finer or coarser cut, according to the quality of the stuff, and for cleaning. The plates may be well immersed in the stuff, and light substances such as rubber, chips of wood, etc., float to the surface and are run off to the auxiliary. Every part is easily accessible for cleaning purposes, and if it is kept in good order there is no waste of stuff from rubber ends, etc.

No spray pipe can be used, therefore all the uncleared fibres and knotty stuff collect on top of the plates and must be periodically removed by the machine assistants. This always causes a rush of stuff to the wire, together with tangled masses of fibres and dirt, and is the worst feature of this strainer.

The strainer vat may be cleaned out, the plates taken off and blown by the steam force jet and replaced in 2 to 3 hours by two men. It is not advisable to run this type of strainer uncleaned for more than a week. Long strings of fibres collect about the inner surfaces of the plates, and are very apt to come away in lumps which do great damage to the wire. Also, it is not unusual for one of the bolts holding a plate on to break or come out, leaving a hole through which the stuff will pass unstrained. It will be readily seen that these strainers are rather expensive to run and keep in good condition, but nevertheless they have proved very efficient in fine mills.

Auxiliary Strainers.—In almost every mill auxiliary strainers or 'back knotters' are used to deal with the stuff rejected by the machine strainers, and they do not usually receive as much attention as they should, either from the machineman or those in authority. The idea of the auxiliary strainer is that it should deal with all the lumps, and heavy stuff rejected by the machine strainers, and also with any scum which may run over, and with the water used to clear the slits. All these contain valuable paper-making material or chemicals, such as size, alum, etc., and if they can be recovered there is a great saving and also a reduction in the mill effluent.

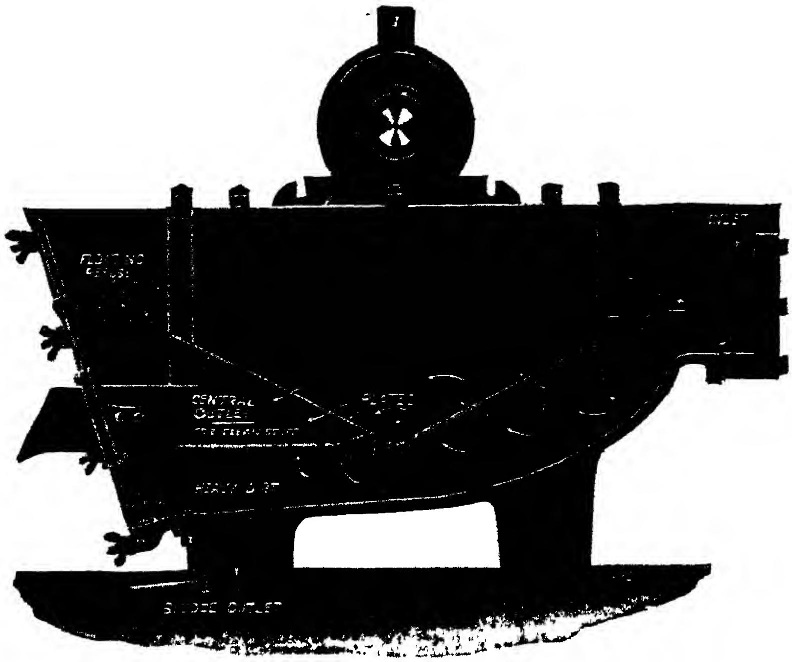
This strainer usually consists of an ordinary flat jog strainer, with a fine cut plate, and it is often placed away in a corner at the back of the other strainers, 'out of sight and out of mind'. It should be placed in a prominent position whenever possible, so that the machineman may see it always receives proper attention, and that others who pass may also see it.

In the case of rag stock, the heavy uncleared lumps and strings which gather in the trough of the strainers, together with the top scum, containing rubber, wood, etc., and the water from the spray pipes, should all be run into it and strained. A good many of the lumps and strings will be broken up, especially

if plenty of water is used, and will pass through and into the back-water system, to be used again.

The rubber and pieces of wood and other light particles will float, and can be scooped off periodically, and thus, besides the great saving which is effected, valuable additional straining is also achieved.

The Watford Engineering Works have given a great deal of attention recently to the production of an efficient auxiliary strainer, and these work very well on fine rag stock and printings. This strainer (Fig. 50) consists of a cast-iron trough, and the strainer plates, which may be either flat or curved, are



[*Watford Engineering Works*

FIG. 50.—THE WATFORD AUXILIARY 'TREMOR' STRAINER

suspended from a shaft which runs in a tube, thus preventing the leakage of any oil from the plummer blocks. A 'tremor' motion is imparted to the shaft, which passes on the 'dither' to the plates. The strainer works very efficiently and is easily cleaned, as the straining portion tips up and exposes the plates. If it is desired, the strainer can be made to work on the 'inward-flow' principle, the strained stuff being passed out through a flexible tube to the back-water pump. In this latter type the heavy stuff remains below the plates in the bottom of the vat, and can be washed out periodically with the hose-pipe.

This strainer, although primarily designed as an auxiliary strainer, is being used successfully in many mills as an ordinary strainer for the stuff itself.

THE FOURDRINIER MACHINE (*Continued*)

Connecting Pipes and Shutes.—The height and situation of the strainers usually decide whether the stuff is run to the breast box through pipes or open shutes. Open shutes are easier to clean, but where pipes must be used they should be of copper, have very smooth interiors and be easily taken apart for cleaning.

Dirt or any rough surface inside the pipes causes clumps of fibres to form. This is very often the cause of a great deal of broke, as these lumps show up very plainly as clear specks or spaces when the paper is finished. For the same reason all shutes must be kept very clean, with no ragged wood or scale, and inside edges should be bevelled or rounded.

The Breast Box.—This is an oblong box extending across the width of the machine. It receives the stuff from the strainers and, overflowing along its whole length, discharges it equally over the breast board. Some machines receiving the stuff from low-level pipes have a series of holes in the bottom of the box. These are connected by smaller pipes to the main stuff pipe. The stuff then flows over the edge of a board on to the breast board. This board is sometimes the cause of clumps of fibres forming in the stuff, especially if its edge is badly trimmed or dirty. The best form of box is V-shaped, whether the stuff falls into it from above or enters at the bottom.

The consistency of the stuff should be equal at the sides and the centre. Where it enters from a series of holes in the box, from one side only, the side of the machine where it enters has always the closest and clearest water-mark, owing to the finest fibres coming first over the edge. The longer and heavier fibres are flung to the other side, and the machineman is often puzzled to know why he cannot get a uniformly made sheet all across the machine.

The whole object of the breast box is to keep the fibres in suspension in the water, and to prevent them from coming together and forming lumps, or settling down, and to ensure an even flow on to the wire, and that all stuff is of equal consistency across the whole width of the machine.

From the breast box the stuff passes on to the breast board, and thence to the apron, or the projection slice. Where an apron is used some sort of connecting device is necessary to bridge the gap from the stationary box to the

oscillating board. This may be accomplished by having the breast box at a sufficiently high level to allow the stuff to pour over the lip into the recess of the breast board. Another way is to bridge the gap with a strip of some strong flexible material which is fixed to both the stationary and the moving board by a continuous strip of metal and counter-sunk screws.

The material called 'moleskin' used to be very popular for the purpose, but its hairy surface makes 'drags' in strong papers. Thin and flexible leather may be obtained for the purpose, and if carefully fixed and used will be found to give good service for about twelve months before having to be renewed. In an emergency, a strip of good old rubber apron will answer the purpose.

The connecting strip should be examined for any cracks or holes when the machine is shut—about once a week, otherwise a loss of stuff may occur and remain undetected for a long time. It should be kept wet over the week-end.

From the breast board the apron receives the stuff and delivers it to the wire. The apron should conform with the following requirements: It must be thin, tough, smooth, non-elastic, composed of a material that will not rub off in pieces or flakes, or wear to a frayed surface, or edge, or wrinkle up with changes of temperature or humidity. Fibrous materials, varnished or water-proofed, are sometimes used, but these cause trouble, since threads at the extreme edge where the material is worn by the wire make streaks and lumps, especially in tinted papers and blues and azures. Even one cotton fibre streaming from the edge, and so small as to be almost invisible, will do this.

The life of the apron depends in a great measure on whether there are many changes of deckle and the care which is taken by the machinemen in making these changes; also on the method of making a reasonably water-tight joint at the first deckle pulley. The best method is the roller apron. The apron is taken underneath a brass plate just inside the pulley and rolled up on a small cylinder which is kept at tension by a cord and weight. This plate is made to be adjusted as close as possible to the wire, leaving just enough space to let the wire run without nipping the apron. The latter is fixed to the breast board by a brass strip and countersunk screws, except for that length at both sides of the machine that is allowed for the maximum and minimum breadth of deckle. A slip of brass, bent to a knee shape, keeps the loose part down on the breast board, and may be pressed down to make a water-tight joint. When drawing out the deckle, the roll on the cylinder must be eased off to let the apron pay out freely and the plate and brass slip put carefully down after the change is made.

When putting the deckle into a narrower width of sheet, the plate and slip should be raised up and the cylinder helped to roll up the loose apron. The

reason for this is that, generally, the weight of the slices and pulleys will cause the cross-bars to sag down a little as they are moved towards the centre, and this must be allowed for, or the apron will be nipped between the plate and the wire.

When the brass plate is fixed or cast in one piece with the deckle pulley fittings, the upright pillars of the cross-rods may be raised. There is usually provision made for this adjustment by having the pillars threaded and held by two nuts.

It is generally found necessary to pack a handful of soft stuff at the outside of the apron on the breast board to prevent fibres coming out and getting under the deckle straps. This arrangement is very efficient and gives a sharp, clean deckle edge to the web of paper. Another method is to fix the apron down on the breast board all across its length and arrange a piece of well-worn old couch cover on the brass plate, so that the empty space between the deckle pulley and deckle strap and the apron is closed up. This projects in a knee shape about 1½ inches over the apron, and allows the deckle to be changed without so much risk of tearing the apron, but is not very effective and requires very skilful handling to give a clear deckle edge.

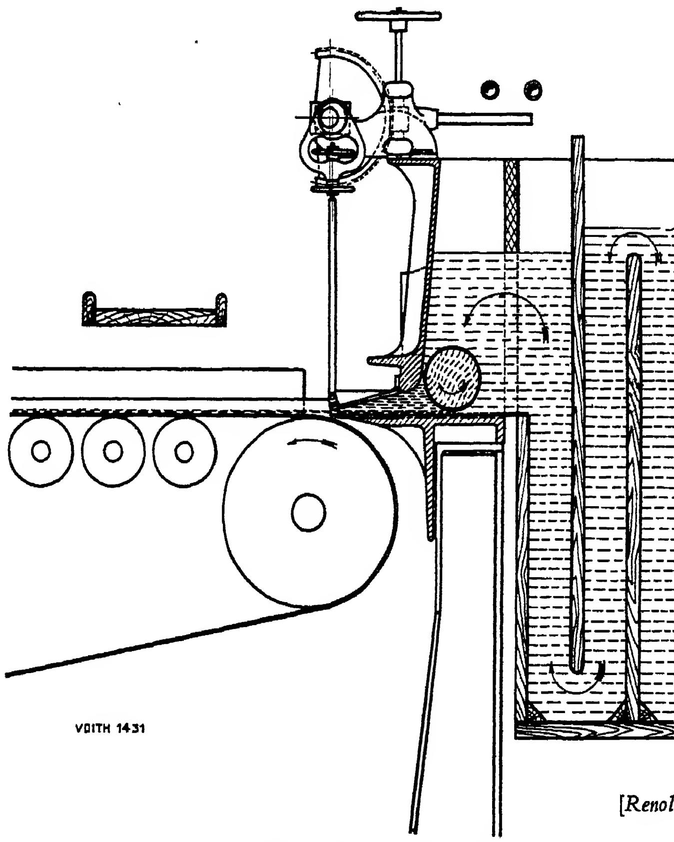
When changing deckles, the apron ought never to be strained or pulled very strongly, or it may then refuse to lie flat. Stuff will then run under the raised part and make continuous streaks or rolls in the paper. A very good plan for getting the apron to lie and remain flat is to utilise an old apron for supporting the new one. The old apron should be cut to about two-thirds of its width and put on underneath and along the new one. This helps to bridge the gap between the lip of the breast board and the highest part of the breast roll, and takes a great deal of strain and wear off the top apron. The lip or wire edge of the apron must coincide with the centre of a tube roll, and all tube rolls under the apron should be kept well oiled and running freely, otherwise air will be drawn through with the wire, causing little holes or clear spots in the paper.

After being put on and once made wet, the apron should never be allowed to get dry; a trickle of water ought to run on to it during the week-end and when there is a shut long enough for it to dry up.

When shutting down, all fibres and any dirt, sand, etc., must be washed off with the hose-pipe from the apron, breast board and connecting devices, towards the breast box. If allowed to get on the wire, it will often be found that these hard substances will pass to the couch rolls and stick in the cover or the guard and score or cut the top couch jacket. A very soft brush or piece of soft felt ought to be sufficient for cleaning the apron, if cleaning is done as often as it should be. This is one of the jobs that the machineman should do

thickness of the stuff stream can be regulated either as a whole, across the full width of the sheet, or locally at any point on the sheet, where for some cause or other there may be a thick or thin place.

The whole stuff gate may be opened or closed at one operation by turning the hand wheel on the front side. The local adjustment is done by vertical screw-threaded spindles secured to the flexible bronze upper lip of the discharge opening (Fig. 52). The adjustments are simple, and can be made by the machineman while the machine is running, and without having to use pieces



[*Renold Marsh Ltd.*

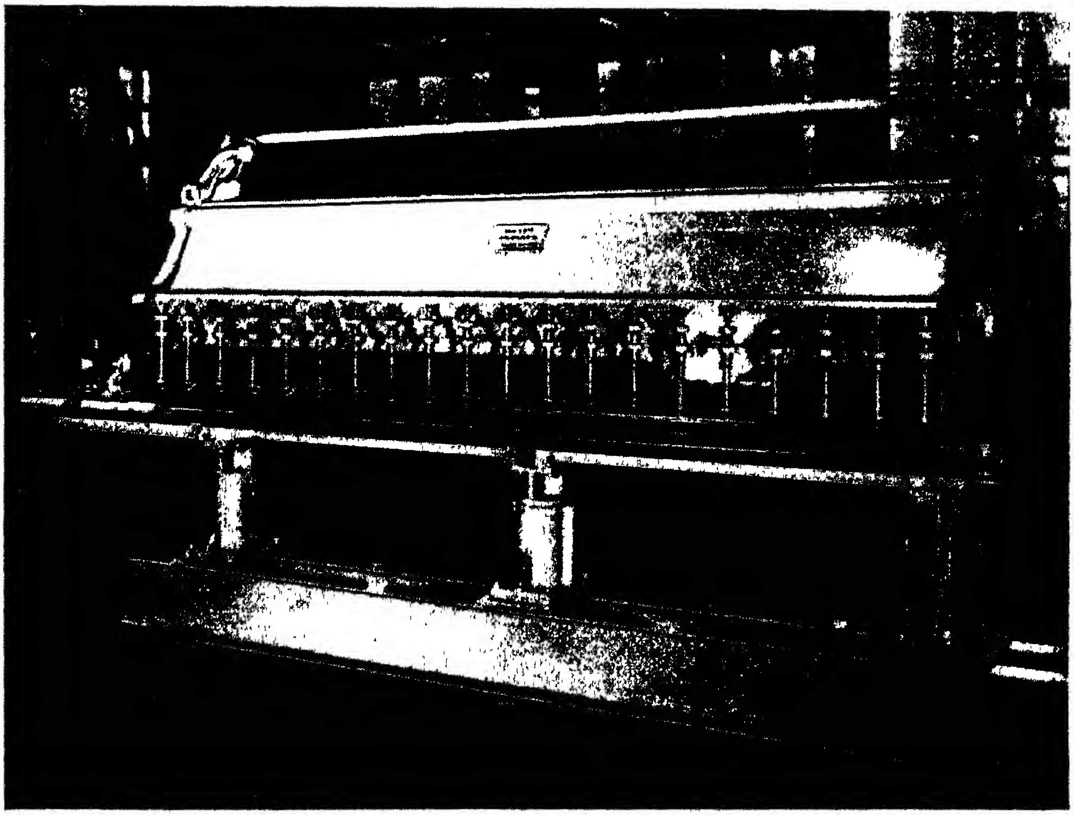
FIG. 51.—VOITH SLICELESS FLOW BOX

of paper on the slice or bits of lead on the apron, or any other troublesome and unsatisfactory makeshifts.

A revolving, perforated copper roll, seen in the illustration (Fig. 51), is placed just behind the discharge opening, and helps to release air bubbles; it also keeps the fibres in a state of agitation, and therefore properly suspended in the water.

The absence of an apron altogether on fast machines, and the use of only a very narrow one on slow machines, saves a great deal of drag on the wire, apart from dispensing altogether with the numerous troubles caused on all machines by aprons, no matter how well they may be fitted.

There is a great saving of wear on the wire, especially on very fast machines, where a very heavy head of stuff has to be maintained behind the usual high slices. No pond at all has to be supported by the wire when a flow box is used. This fact gives also greater 'making' length of wire to the machine, as the stuff has more room to felt and begins to drain at the breast roll itself. The box keeps back the froth which continually forms behind the slices, and comes away with variations in the amount of water or state of the stuff from the beaters. It is very easily washed down when changing, and if good sprays



[*Renold Marsh Ltd.*

FIG. 52.—LATEST ADJUSTABLE TYPE VOITH SLICELESS FLOW BOX
The flexible lip and adjusting rods are clearly shown

are kept in operation above the stuff behind the box there is very little trouble from air bells.

The flow box is giving great satisfaction on many machines at present, and is especially satisfactory on fast machines, although it is equally effective on slow and 'fine' machines.

Usually the principle of getting stuff satisfactorily on to the wire from the breast box is to cause it to flow on at the same speed as the wire is travelling except when special features are required, such as cloudiness in a ledger paper.

It thus becomes a question of adjusting the weight of the head of stuff to give a pressure sufficient to force the stuff forward at the correct speed. Until the introduction of the Voith box very little attention had been paid to this important subject, and in most cases the stuff came slowly forward until caught by the wire, and it was then whisked suddenly forward and rolled into waves and generally disturbed, when it should have been coming under the action of the shake and been properly felted together.

It can therefore be said that the use of the flow box helps very considerably in forming a better and stronger sheet. The amount of stuff for a given substance and speed is, of course, still regulated by the stuff and back-water taps, but the head of stuff behind the box, to give the required speed of discharge on to the wire, is regulated by the opening of the lips of the gate.

The correct adjustment of the gate and head of stuff must, of course, be found by the machineman himself, according to the substance he is making and the speed of the machine, just in the same way as he had to find these adjustments with his slices. The adjustment, however, is far more easily controlled, both for the whole width of the machine—by turning a wheel—and for any individual unequal patches by screwing the adjusting spindles up or down. It has one great disadvantage, however, in that it cannot be used satisfactorily where there are many changes of deckle width. When a slice is used it should be high, so as to allow a deep pond to be worked; 18 inches is not too high for a machine running up to 650 feet per minute, and very much higher for fast speeds and free stuff.

The Wire.—The wire is the most delicate and expensive part of the machine equipment. It may be described as a sheet of fine wire gauze, joined by a seam to form a continuous band.

The fineness of the wire, its texture and mesh, are made to suit the class of paper for which it has to be used, and the speed at which it is to be run. The wire is made of bronze of various alloys of copper, tin, etc., and these are varied by the makers to obtain a combination of strength, durability, and wearing qualities.

Machine wires may be obtained in a wide range of mesh and quality, and in various types of weave. The old weave seems now to be giving place to long crimp, flat-warp, and twill types of weave for which various advantages are claimed, and the wire-makers are continuously experimenting with different weaves, to give strength and wearing qualities, and smoothness to the under side of the sheet of paper, so that the surface of the under side may be as nearly as possible equal to that of the top side.

Great praise is due to the energy and extensive research work of the paper machine wire manufacturers, who do their utmost to give the paper-makers

exactly what they want, and enormous strides have been made in the improvement of wires and in the method of making the join during the last few years. At this stage it is desirable to outline briefly some of these developments.

The first radical change in the construction of paper machine wires was the introduction of long crimp or twill weave. This was done with the object of increasing the life of the wire, and was first introduced for the manufacture of newsprint. It remained as such for a considerable number of years. The wire mark caused by this particular weave of wire was different from anything previously known, and in a number of early cases was considered objectionable. Various improvements in the weaving, however, have modified this mark in the under side of the paper, and in nearly every case newsprint is manufactured over twill wires, certainly on the wide machines 19 feet and over in width.

Various developments and improvements of the twill weave permitted its application for the manufacture of finer papers, and various weaves are now on the market known under the different titles applied to them by their various makers, such as Superfine Quality, Flat Warp, etc., the object of these fine weaves being to present as many places of support as possible to the under side of the sheet during formation, and so prevent any prominent knuckle imprinting itself into the web. The question of wire mark is no longer the source of worry that it used to be to the fine paper-maker, and in some cases in paper made on these new weaves it has been almost impossible for anybody but the expert to say which was the top side and which the under side. The paper-maker, therefore, who wishes to avoid wire mark must co-operate with the wire-makers to provide him with the most suitable formation of weave for his purpose.

Another very valuable attribute of these wires is the improved shape of hole. In the ordinary plain weave the hole is of a very oblong shape, whereas with the newer weave it is very much squarer, with a consequent reduction in the loss of fine fibres. This can be readily seen by a comparison between Figs. 53 and 54, both of which are 72-mesh photographed at the same magnification, but No. 1 is the old plain weave and No. 2 a Superfine equal to 72. It is particularly interesting to note that the use of 90, 80 and practically all 76-mesh wires of plain weave has been discontinued in favour of these new weaves, with none of which it is necessary to go finer than 72.

It is not unusual, however, for mills making a wide range of papers, both of quality and substance, to keep to one mesh and to vary the furnish and beating to prevent 'wire mark', or to enable the paper to run on a fine mesh wire.

When there is more than one machine, it is more economical and efficient to use wires with different meshes and run on each the quality that is best suited to it

The *length* of the wire depends on various circumstances, chief of which are the speed of the machine and the quality of the paper. It is obvious that the longer the wire the more water will drain from the stuff through the action of the tube rolls before it reaches the suction boxes. Hence for heavy substances and rag papers a long wire is indicated, to run at an economical speed. On the other hand, if banks have to be made on the same machine, too little water would be carried to the dandy roll to have a good control of the watermark. Therefore a compromise has to be made, and the length of the wire has to be decided by all the circumstances, including very often the space available. From 40 to 60 feet give good average results, with from 16 to

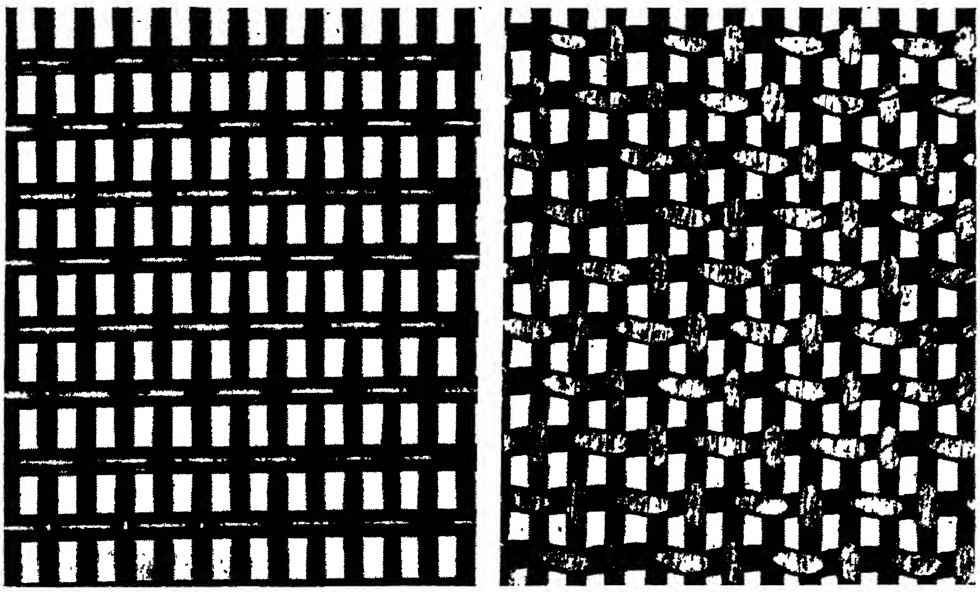


FIG. 53 FIG. 54

[*The United Wire Works Ltd.*

FIGS. 53 AND 54.—PHOTOGRAPHS AT THE SAME MAGNIFICATION OF PLAIN WEAVE AND SUPERFINE WEAVE 72 MESH

30 tube rolls, according to their size and the speed at which the machine is to run.

This question of length of machine wire has always been a subject of controversy among paper-makers, but before stating definitely what length of wire is most suitable for a machine making certain classes of paper it is necessary to take a variety of subjects into consideration.

Other things being equal, the machine on which very wet or highly fibrillated stock has to be worked will require a longer wire than one on which only free stuff is worked.

The reason for this is that the wire is simply a filter for removing the water and receiving the fibre deposit upon its surface. It is true that the sheet or

web is formed on the wire, and that sheets of different formation and appearance may be made on the same wire by altering slightly the lateral movement of the wire frame and/or the amount of water in the stock, but the formation of the sheet—even of a very strong sheet—is accomplished in a very short distance along the wire. After the stuff has settled down—say half-way along the wire—no change in the position of alignment of the fibres appears to take place, and the wire is simply carrying the web along to the first suction box. There is something else happening, however—*i.e.*, the removal of water by each of the tube rolls. This water can be just as well removed by an extra suction box or two, so that the difficulty of a short wire can be easily overcome.

On these machines where a Voith slice is used it is no longer necessary to take up 2 or 3 feet of wire by covering it with an apron or pond of stuff behind the slices, so that this gives more actual paper-making length on the wire.

It must be remembered, however, that there is a tendency now to prevent water being taken out by the first few table rolls, in order that the effect of the shake may be brought to bear on the fibres while they are still floating in water which is not passing away through the wire. There is also a tendency for table rolls to be substituted by flat boards or smooth surfaces of stationary metal for the first 12 inches or more of the wire after it leaves the breast roll.

There are a good many fairly old machines running at the present time on which very strong rag papers are made, where great difficulty is experienced in getting the water out before the dandy and couch roll, resulting in 'crushing' and spoiling of the sheet. Sometimes it is quite impossible to make the required sheet for the following reasons:

1. The stuff is too wet and the wire too short for water extraction, if sufficient water is put on to 'make' the sheet.

2. If water is put off at the stuff box the stuff is too inert and greasy to shake together properly when it reaches the wire. It will also be found that if water is put off the stuff cannot be got through the strainer, especially if it is long as well as wet.

3. If sufficient water is put on to get the stuff through the strainer and to make the sheet on the wire, then there is too much water at the dandy and couch rolls. Heating the stuff will help matters, but in order to get over the difficulty permanently there are two alternatives only. First, to put in one or two more suction boxes, with *separate* vacuum pumps, or increase the length of the wire and the number of tube rolls.

Really wet, thick stuff, for strong ledgers, parts very slowly with its water, and *gradual but not too fierce* suction is necessary if the work is to be properly done.

The Seam.—This is the place where the two ends of the wire cloth have

been joined, and whilst not so many years ago this was a source of worry and trouble to everybody connected with the use of machine wires, the enormous improvements which have been made in the construction of the seam due to the research work expended has altered the position entirely. Perhaps no one particular type of modern seam has any advantage over the other. Some are welded, others soldered, but those constructed in the newest manner with the latest available technique should be equal to the strength of the wire itself, nor should they make any mark in the paper, or if they do it should be the very minimum.

As a matter of interest a plan view (Fig. 55) is shown of one of the very

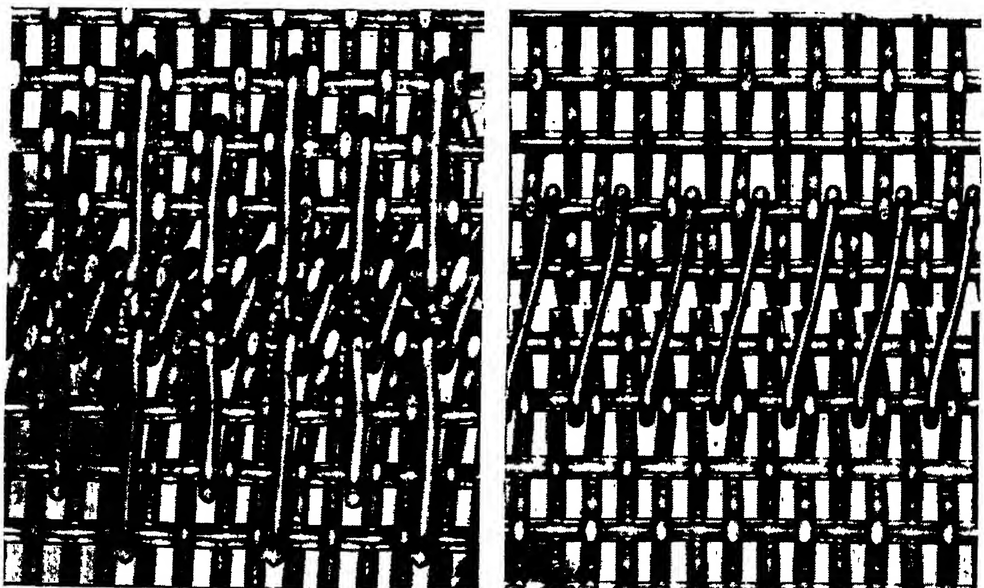


Fig. 55 Fig 56

[*The United Wire Works Ltd.*

Figs. 55 and 56.—Photographs of Hand-Sewn Seams

Fig. 55 shows how drainage is interfered with in the old type of seam, while Fig. 56 shows a more modern sewing, in which the drainage is much improved

early types of seams, and Fig. 56 of a little more modern seam, both hand-sewn. Fig. 57 is a modern welded joint; Fig. 58 is a soldered joint. It will be observed that in the welded or soldered joints there is practically no obstruction to the drainage.

There is, however, one condition which even welded or soldered joints will not withstand, nor for that matter any wire, and that is grooving or freezing to the suction boxes. This is a point which should be understood by every paper-maker, foreman and machineman who wishes to get the best results from his wires. By the term 'grooving' is meant that each individual warp wire as it travels across the boxes wears a channel into the top. If there are

60 warp wires, then there are 60 channels formed in the top of the boxes, which, if the trouble is allowed to continue, will have a formation like a miniature piece of corrugated paper. Obviously when this condition has arisen it is impossible for the wire to travel laterally across the boxes, an essential factor to the successful running of a paper machine wire. It will be readily understood that when the slightly thickened blobs of the weld at the joint meet the grooves they will not fit into the grooves, as they are larger in diameter than the wire which formed the groove. This consequently raises the wire a small fraction off the top of the boxes, making a momentary break in the vacuum, with a consequent mark in the paper. This is also applicable to a soldered

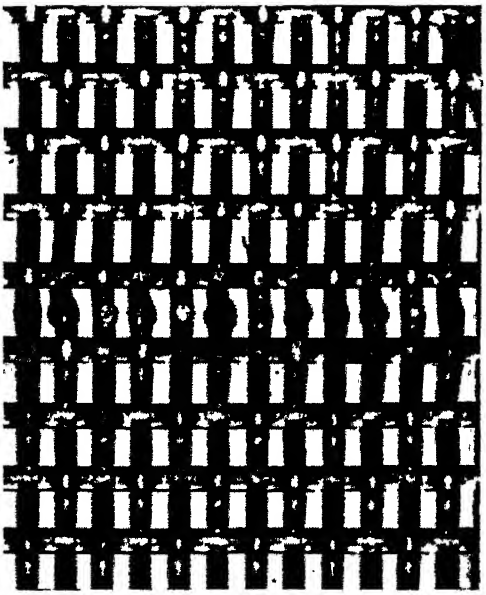


FIG. 57

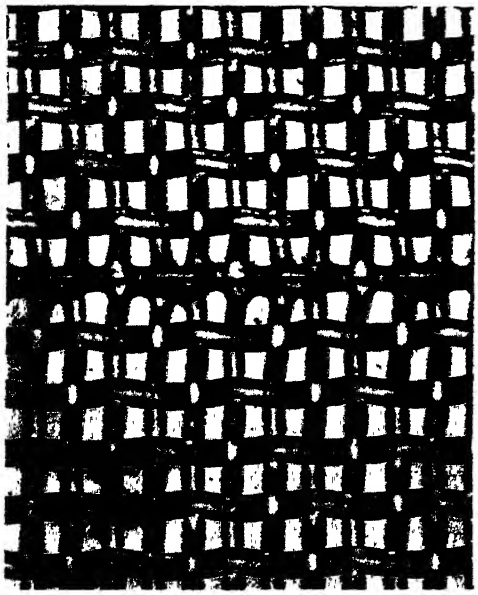


FIG. 58

[*The United Wire Works Ltd.*

FIGS. 57 AND 58.—WELDED AND SOLDERED JOINTS.

joint. Not only does this objectionable feature wear out the joint, but it also wears out the whole wire by causing grooves in every under-side warp knuckle as it tries to travel to right or left across the boxes.

Fig. 59 is a plan view of the under side of a hand-sewn seam which has been allowed to groove, and Fig. 60 is a plan view of the under side of a twill wire similarly worn.

Close observation of the wire when in operation should readily reveal when it is grooving. In the first place a knock can often be heard as the joint hits the front of the suction boxes, but apart from this the under side of the wire shines and glistens very brightly as compared to a wire running in the normal manner.

The remedy, of course, is to shift slightly the offending box or boxes, or if this fails to overcome the trouble, then it may be necessary to remove the suction boxes from the machine and face up the tops.

Machine wire manufacturers have their own methods of overcoming this objectionable feature, but up to date it appears that whilst they have been successful in 99 per cent of cases, there are still the odd few which give trouble, and when they do it is trouble indeed unless immediate steps are taken to counteract the fault.

The life of a wire is the length of time it runs or, more correctly, the weight of paper made during that time. But it can readily be understood that no

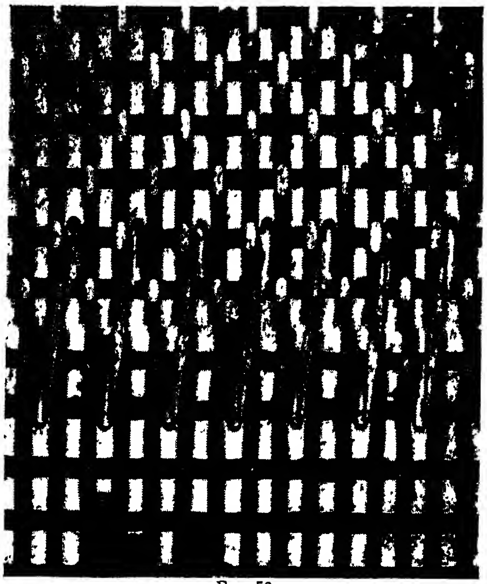


FIG. 59

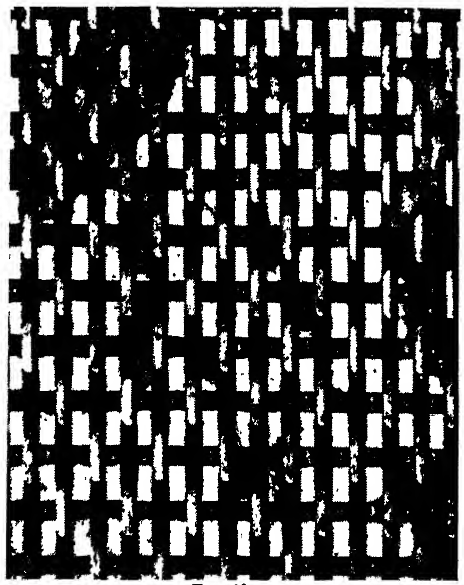


FIG. 60

[*The United Wire Works Ltd.*

FIGS. 59 AND 60.—PHOTOGRAPHS OF THE UNDER SIDES OF HAND-SEWN SEAM AND TWILL WIRE, BOTH OF WHICH HAVE BEEN ALLOWED TO GROOVE

definite time or weight can be calculated on, since a machine making thin papers will wear out a wire with less output than one making heavier substances with the same width. The factors that influence the life of a wire are of two kinds. First, the care taken of the wire by the machinemen and their skill in its use, and accidental damage; secondly, those agencies which are constant and unavoidable.

In the first may be placed the putting on of the wire when new. Without going into all the details of putting a new wire on the machine, we will just mention some of the items where damage may be done and how to avoid it.

The box containing the wire must be carefully opened. The screws which fasten the lid should be withdrawn entirely by the screw-driver and removed.

The wire will be found packed with straw or fine wood shavings, and jammed endways by means of two pieces of wood nailed to the ends of the rollers or poles on which it is wound. It is lifted out of the box and laid on a long table, on which there are no other objects, such as spanners, nails, etc. The two pieces of board are then knocked off—a smart blow with the palm of the hand will suffice—and the rollers firmly held until both ends are clear. The covering wrappers, on which will be found the 'certificate' (number, date, etc.), are ripped off with the fingers, never with a knife or other hard tool. There will be three poles or rollers, two of which are in the centre of the web; the other is inside, and protects the loose end, and all three are firmly bound in position at the ends. The binding is cut while the third pole is held in position by one man at each end, and no attempt must be made to move the position of the pole until both ends are loose. It should then be laid gently on the table, thus unwinding the first turn, and withdrawn. When doing this, the machineman should superintend and make sure that it is slowly and evenly drawn out, and that nobody knocks the end in the process. Though the lid of the box may be unscrewed, it is safest to leave the wire in the box until the machine is quite ready for its reception.

The most difficult part of the work is then proceeded with. Two men with strong hands and wrists lift the wire, by means of the ends of the two remaining poles, slowly upwards from the table, and the loose end swings free and must not be touched. It is advisable to steady the wire and assist in supporting its weight by placing two men opposite the loose end, with the palms of their hands under the roll. All obstacles should be removed from the floor, in case a man should trip. The wire is held in line with the bottom couch roll, which is supported by a jack or block near the centre and stands pointing clear of the frame or brackets of the machine. The roll of wire is then unwound far enough to allow the loose end to form a loop big enough to receive the couch roll. This loop must be opened out by a machineman standing inside the frame, but there should be another man at the opposite side of the wire acting in concert and keeping the wire tight from side to side; otherwise, if it is attempted to open out the loop at one side only, the wire will be buckled and the mark will be permanent. In this position the wire is advanced as far as the supporting block, when an extension is put through the loop and takes hold of the couch-roll spindle. The weight of the roll is then taken with this extension shaft, the block removed, and the wire slowly and carefully carried over the roll. It will be found that if the latter is jacketed the edge of the wire will not slip over it freely, but will be held by the hair of the cover. This must be watched for and guarded against. Once safely on the bottom couch roll, there is not much danger of damaging

the wire if ordinary care is taken in putting through the breast and other rolls.

The wire must be supported by two poles when putting in the 'tube rolls'. These poles must be held at the same height and tension, and when moved forward as the tubes are placed in position it should be done slowly and in the same parallel, or the wire may be buckled or wrinkled. When all the rolls are in position and the suction boxes are levelled, the stretch roll should be allowed to tighten the wire by its own weight only.

Then the machinemen should examine all the arrangements and see that no pieces of wood from the save-alls or suction boxes, etc., have fallen on the inside of the wire. The wire rolls will, of course, have been cleaned and washed before being put in, but the hose-pipe should be freely used again. A very wise precaution is to start the machine slowly and run the wire round a few turns to allow it to straighten itself out, all watching carefully for any defect or damage.

No attempt should be made to straighten the seam if it is out of square with the edge of the wire. A slight slope is an inherent feature in some forms of twill-woven wires and causes no trouble or difficulties in running.

If there is a top couch roll which has the effect of tightening the wire, the stretch roll has to be freed to keep no more tension than its own weight until the machineman finally tensions it.

Care of the Wire.—It is necessary at all times to keep a close watch on the wire, and more especially when starting up. The wash roll under the wire, which is cleaned by a doctor board, does not always start if the wire is not very tight, and this may be the cause of stuff getting on to the next roll and making a ridge in the wire. A very sharp spray of water is essential here; it should strike the wire from the inside and impinge on the roll itself, or, better still, two sprays are more effective, one spraying through the wire a few inches before it reaches the wash roll, and the other after it passes the roll and impinging on the roll at the contact point of the doctor board.

The breast roll also is a source of danger if the doctor board is not true all across, since a very small piece of pulp or foreign substance may pass, or even a layer of scale form, from the water getting through. Water passing the doctor at a part where the latter fits badly will cause a ridge in the wire, if the speed of the roll is high enough to carry the water round and under the wire. Where wood pulp is used a very stiff and close-fitting doctor board is required to scrape off sulphite pitch.

Before he starts the wire, the machineman ought to have a good hose-pipe handy, with the water turned full on, ready to wash off the wire rolls as soon as the paper is on the felt. If the stuff should run up the top couch roll, this

hose-pipe may be immediately used to wash it down the wire. In this case, if any stuff has got jammed in the nip of the guard board, when the board is lifted to free it the piece must be caught before it drops down on the wire. It is the practice in some mills to use a 'starting sheet'. This is laid on the stuff as it reaches the suction boxes and may be easily caught coming through the couch rolls, and serves to lead the wet sheet on to the felt. If the machine is started with the dandy roll running on the wire, this introduces an *unnecessary* element of risk, since the stuff is seldom correct for taking a water mark when it first reaches the first suction box.

Bits will be picked up by the roll, and may attain some thickness, layer by layer, before they can be got off, generally to fall on the wire and go through the couch rolls. Or it may happen that the stuff is more wet or more free than the machineman has calculated on, or he may have too much or too little stuff or water. The presence of the dandy roll then adds immensely to his difficulties. If the roll is not down, the suction boxes have a far greater chance of taking water out of the sheet. When the machineman has got his stuff and water suitably proportioned and his level approximately correct, he may lower his dandy roll on to the paper with confidence. On moving the ends of the suction boxes, or when packing them with stuff, bits may be carried round and on to the wire rolls. An accident that is not uncommon happens when a piece of some foreign substance, such as small stone, piece of cement, or sandy particle, is washed into the wire by the indiscreet use of the hose-pipe on the floor in front of the wire.

The hose-pipe, when washing up the floor, must always be directed to send the jet *away* from the wire.

An uncovered strap or pulley may fling a piece of fibre, or even a belt fastener or rivet, into the wire, or on to the table. A machineman should be careful to have all the buttons on his clothing firmly sewn on and to remove his collar studs when he takes charge. Any one of these may fall or jerk on to the wire when he leans over the slices or other adjustments. When putting on or repairing connecting strips or aprons, all tacks, screws, pieces of rubber, etc., and all tools should be picked up and accounted for before moving the wire again. When removing stringy fibres from the slices, no hard, pointed instrument may be employed. The best method is to run the tip of the finger along the edge.

No spanners, broke, etc., should be thrown down near the wire, and the space both at back and front should be kept clean and as clear of all machine-house fittings as possible. Shake must be stopped as soon as paper is off the wire.

When the machine is shut for the week-end, sufficient sprays to keep the

wire wet should be left on. Some managers insist that all water be shut off in the machine room, but when this is done suction boxes, couch-roll covers, apron and connecting straps dry up and get spoiled by shrinkage, etc., with loss of time and bad work when starting up again. But unless every part of the wire is kept wet, or if a draught dries up a space, a 'tide mark' will be formed which is very difficult to clean. A very old custom is to leave the wire seam over the week-end in the nip of the couch rolls, 'to keep it flat', but it is obvious that it can do no good, but only harm, for the seam to be under heavy pressure for any length of time. The best place to leave the seam is on the breast roll.

The second set of factors which influence the life of the wire are, generally speaking, constant and unavoidable, though some may be minimised if proper precautions are taken. One of the worst enemies of the wire is the necessity of using hard water, which forms deposits of calcium carbonate. The latter, however, and the general clogging up of the mesh of the wire by loading, size, etc., are to a very great extent preventable and depend on several things, which will be touched on later.

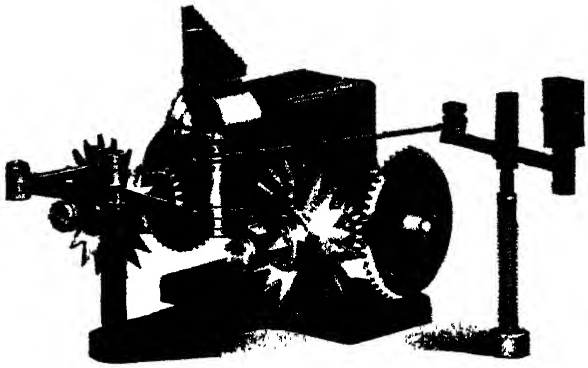
As far as the machineman is concerned, it will be found that if he adjusts his back-water system carefully he will use the same water over and over again, with very little addition of fresh water, which causes the deposits. Except where special treatment of whitewater is carried out, fresh water must of necessity be used in the sprays of the wire rolls, so that after a period the wire clogs up and must be cleaned. A steam force jet, judiciously used—say once a week—will help to lengthen this period, but there are now special cleaning agents on the market which clean the wires with less damage than sulphuric acid.

Hydrochloric acid may be used to clean the wire of limy deposits. A 50 per cent solution from an earthenware or glass bottle should be applied to the top of the wire with an old scrubbing brush, and washed out with the force jet before the solution reaches the couch roll.

Then there is the wear of the wire by the rolls and tops of the suction boxes. As far as the rolls are concerned, they should be kept well lubricated, and especially the tube rolls which form the table. Also, any side play on their spindles or brasses must be watched for, as in this case the action of the shake will make the wear much greater. The weight of the breast roll is important. Very often it is made too heavy, thus imposing an unnecessary strain on the wire in pulling it round, and more so when starting up. Deckle straps, where there are many changes of sorts, make the wire dirty and cause more or less ridging; so also do the movable ends of the suction boxes, owing to there being a pull over their inner edges. The shake has a twisting action on the wire

just before it is held by the suction boxes. Dandy rolls that are too short and have prominent discs on their ends are a source of trouble. Cracks on the edges of the wire are often caused by the 'spades' of the guide roll stick.

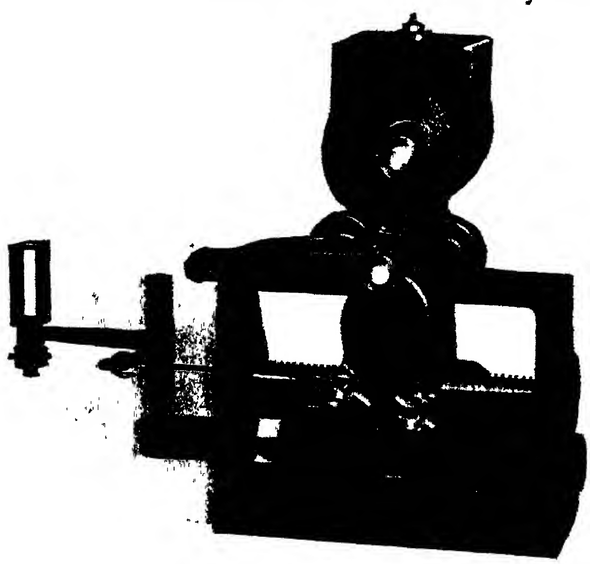
Setting and Running the Wire.—After a new wire has been put on, and all



[*James Bertram and Sons Ltd.*

Fig. 62.—Automatic Wire Guide

fittings have been replaced, it is necessary to tension and 'set' the wire, so that it will answer to the guide (Figs. 62 and 63), keep in the centre of the machine, and make an equally couched and uniform sheet. With the stretch roll swinging freely and the top couch roll with equal weight on both sides, the new wire should run for a few minutes and be worked by hand guidance to the



[*James Bertram and Sons Ltd.*

Fig. 63.—Automatic Wire Guide

centre of the rolls. The guide-bar spades are then fixed close to the edges of the wire. There is no need to leave any space for the wire to move; unless it has an irregular or a waved edge, when sufficient is left to keep the edges

from being rubbed and frayed. A few more turns will show whether the guide roll is set so as to be able to keep the wire in position.

The stretch roll may now be put down a little if it is light and experience shows that it is necessary. A heavy roll will not require to be put down, but its spindles should have enough pressure to keep it from jumping. On starting again, if the seam is fairly straight and the tension from the boxes to the couch rolls is equal on both sides, it may be assumed that the wire is correct for a start-up with paper.

There is, however, a very great difference in the running of a wire without stuff and with stuff. In the latter case the suction boxes hold the wire, and the couch rolls have to pull it across them, thus creating a tension which is very much greater at this point than anywhere else. Therefore the top coucher has the most important influence on the wire. The slightest difference in the pressure applied alters the tension between the boxes and the nip. This may possibly be so much that the wire is extremely tight at one side and so slack at the other that it is impossible to keep it in the centre of the machine, the guide roll being unable to send it back to its place.

Then the tension of the stretch roll will be found to be greatest on that side where the tension from the boxes to the nip is least. It is here that a machineman may make a mistake by altering the stretch roll in an attempt to straighten the wire. Instead, weight must be taken off the couch roll on the side which is slack, between the boxes and the couch roll, until both sides have the same tension. Then the seam should be carefully watched, and if any alteration is necessary, the stretch roll may be put down on the side which is leading. The alteration may change the tension at the nip a little, and both sides of the wire must be carefully watched until the tension remains the same and the seam is straight. It will then be found that the wire will keep well in position and be guided by the ordinary automatic movement of the guide roll.

If the stretch roll is not quite level, this is immaterial so long as the seam is straight and the tension is correct, since some wires appear to have a slack side. This is very difficult to decide, because it is possible for this appearance to be caused by the inclination of the couch rolls or wear in any of the brasses of the wire or breast rolls. For this reason it is very much worth while for the engineers to test these things when the wire is being renewed. In particular, the back-side brasses of the bottom couch roll tend to have more wear owing to the pull of the clutch, and perhaps to having less attention paid to them in regard to cleaning and oiling. When this happens the back shaft and the couch rolls are not in alignment, and the result is an eccentric action in the clutch which causes a rise and fall of the couchers.

It often happens that a wire will travel slowly to one side of the machine and cling there, in spite of the guide roll being fully set to bring it into its place. This is more inclined to be at the back side than the fore side, because the guide roll has to turn on the back side as a pivot, and therefore has less control of the wire at that side. There is very great danger in this situation, and a machineman has to be very much on the alert lest the wire turn suddenly and come over too quickly, doubling up its edges on the guide-bar spades. But assuming that no further alteration of the guide roll is possible, and the wire shows an inclination to go too far, then the suction may be partly shut off the last box, or the air valve opened a little. Then the wire will return to its place with a run, which can be quickly checked by again putting on the full suction and squaring up the guide roll. This will seldom take place if the tension from the boxes to the nip is properly adjusted, but it must be clearly understood that the coucher must not be used to control the wire.

It may happen that a wire will run very well with the sides at the nip not equally tight, so long as the paper and suction are on it; but couching will be unequal, because the tight side has the least weight on it. In this case, if the machine is shutting down and the wire runs empty for a few turns, the heavier-weighted side may slacken so much more as to run through the nip in wrinkles, when the wire is rendered entirely useless.

For this reason it is very inadvisable to run the wire empty for more than a turn or two to clean it off, unless the machineman is very sure that his coucher weights are perfectly adjusted.

The level of the guide roll to the last suction box has a very important bearing on the steady and trustworthy guiding of the wire. If the guide roll is too low, the suction box will control the wire in spite of the roll. This is shown by a wire running to one side and coming back with a dangerous run when the suction is eased off. The guide roll may work very far forward to send the wire back, or *vice versa*, and this introduces another complication which makes matters worse. The roll being too far advanced—say at the front side—and the wire tending to come to that side, the wire is thereby tightened up between the box and the coucher. This in itself ensures the tendency of the wire to come forward, since a wire will always run towards the side on which the wire is tightest, between the box and the couch roll. The guide roll should in all cases be just so much under the level of the last suction box as not to interfere with the suction; $\frac{1}{16}$ inch is quite sufficient. Most of the machineman's uncertainty as to the guiding of his wire will be eliminated if this vital point is attended to.

The Tube Rolls.—The tube rolls have two functions: First, they support the wire from the breast roll to the suction boxes, and form a table with the

wire on which the stuff and water are evenly spread and formed into paper. For this purpose they must be accurately levelled from side to side and to each other, and at every renewal of the wire, examined and thoroughly cleaned. Great care should be taken in replacing them in their proper order. They are usually numbered for convenience. A safe place should be selected for them to lie until they are put back.

[*James Bertram and Sons Ltd.*

FIG. 64.—LATEST TYPE SHAKE MOTION, WITH VARIABLE SPEED MOTOR FOR SPEED ALTERATION

The stroke is altered by the hand wheel

Although paper machines will run satisfactorily and make good paper with stationary tube rolls, it is usual to have these rolls fitted with very free-running bearings. If the bearings are ordinary brass, they should be kept well and regularly greased or oiled. Ball bearings are now available which will withstand the conditions and keep out water, and they are in every case to be recommended.

It is important that the tube rolls should be of a sufficient diameter to enable the usual speed to be run, without the throwing of water from the rolls. In some cases it is necessary to put doctors on the tube rolls, or baffle plates, to catch the water thrown off by the roll and prevent it being taken up to the wire again.

Their second function is to draw water from the sheet. A layer of water forms on the under side of the wire, a tube roll rubs or drains it away, leaving a partial vacuum in each minute pore of the wire. This immediately fills with water and is emptied by the next roll. Thus it will be seen that the number of tube rolls has a definite relation to the length of the wire.

A short wire, closely tubed, can deal with wet stuff, as far as extraction of water is concerned, nearly, if not quite, as well as a longer wire with the same number of tube rolls.

The Shake.—For the purpose of closing up the fibres into a compact sheet it is necessary to impart a sideways shake to the wire. This is accomplished by a crank and shaft driven through cone pulleys so that the speed may be adjusted to suit the stuff. On old machines the frame of the wire at the breast roll was supported on rocking standards. The fault of this arrangement was that the brasses of the crank, etc., had to withstand the shock of changing the direction of the throw very suddenly and soon wore down and developed a knock. An excellent shake motion (Fig. 64) is now manufactured by Messrs. James Bertram and Sons Ltd.; in this the eccentric runs entirely enclosed in an oil bath, and the wear in consequence is practically nil. This shake motion has no cone pulleys, as it is driven by a variable speed motor.

On modern machines the frame is hung or supported on flexible steel hinges or springs, so that the action becomes a soft swing, instead of a hard jerk. About $\frac{1}{8}$ to $\frac{1}{16}$ inch is an average length of throw, but it is a great advantage to have an arrangement to allow of the length being altered, when running, to suit different papers. A loose pulley or clutch is necessary to stop the shake when the wire is not running.

The level or slope of the wire from the breast roll to the suction boxes depends on the speed of the machine, and in some degree also on the quality of the paper made.

Machines for high-speed work have the wire frame supported by adjustable standards, to alter the slope of the wire as the speed is put up. A machine making newsprint at 1000 feet per minute may require a slope down from the breast to the suction boxes of as much as 18 inches.

Slow-running machines making strong ledger papers from rags, with a 40-feet wire, may need a rise of 2 inches from the breast to the boxes. A rise of 1 to $1\frac{1}{2}$ inches on a 40-feet wire making good-class water-marked papers up to 120 feet per minute would be about right.

CHAPTER XIII

THE FOURDRINIER MACHINE (*Continued*)

Deckle Straps to Machine Drive

Deckle Straps.—These are the endless rubber bands which keep the stuff on the wire. They are composed of flexible rubber with a core of harder and stronger material to give them stability. They should be of sufficient weight and bulk to prevent the stuff from flowing under or pressing them outwards. They are carried on flanged pulleys, movable outwards or inwards to suit different widths of web. Often deckle straps are far too big and heavy, and they cause a strain on the wire, and frequently damage it. A deckle strap should never be heavier or longer than is absolutely necessary. It is possible on some machines to manage with deckle straps only about 7 feet between centres, depending on how the stuff parts with its water. Various means have been suggested and tried out in order to supersede the rubber deckle strap, but in our experience these have been very unsatisfactory on the whole, and we are inclined to think that, at the present time, there is nothing available which will give such general satisfaction as the ordinary rubber deckle strap.

A trickle of water must be continually run on the inside of the straps; otherwise they will soon become dry and stick to the pulleys. If this happens a strap may stop, and this often means a ruined wire, owing to hard rolls of pulp going through the couch rolls. Bruises or cracks on the edge next the wire will result in a little 'leaf' being formed on the edge of the paper, with a corresponding thin place behind it.

This may be picked up by the press rolls and cause a break there or at the dry end of the machine. If the edges of the strap are rough, uneven, dirty, or have a hard lump, the same trouble will result. If a strap is too long, the return portion will swing and sag and cause it to move forward on the wire with a jerky motion. If too short, or with perished and sticky places, it will drag and make rolls of pulp on the deckle edge.

It is important that the side that runs on the wire should be slightly concave, otherwise there will be a continuous bad edge. It often happens that a strap is bruised or otherwise damaged when changing a wire. Therefore too great care cannot be taken to see that they are skilfully handled, placed where there

is no probability of their being made greasy, and well away from the work going on, until they are replaced. If spare straps are kept, and this is a wise precaution, they must be stored in a cool damp place, and kept in such a position that they have not to take any acute bend or twist, as after a time this will become permanent and render them useless.

When changing deckles, the pins holding the deckle pulleys may be slacked off and the pulleys assisted to move in the required direction. If the strap runs off the pulleys, the wire may be scored and the strap damaged. It must not be forgotten to tighten up the pins again; they may drop out and be carried through the couch rolls, with disastrous results.

The deckle pulleys ought to be oiled and wiped clean at every opportunity. A stiff-running pulley will make the strap jerky and cause a lot of breaks before the source is discovered.

Suction Boxes.—Many machines have only two suction boxes. For making paper from rag stock, when we sometimes get very wet stuff, two boxes are insufficient. In any case, three or more boxes are better than two. Even if the paper we make could be worked with two, it is wiser to have a little suction on each of three or four than a strong suction on two, for then less pressure is put on the wire, which lengthens its period of use.

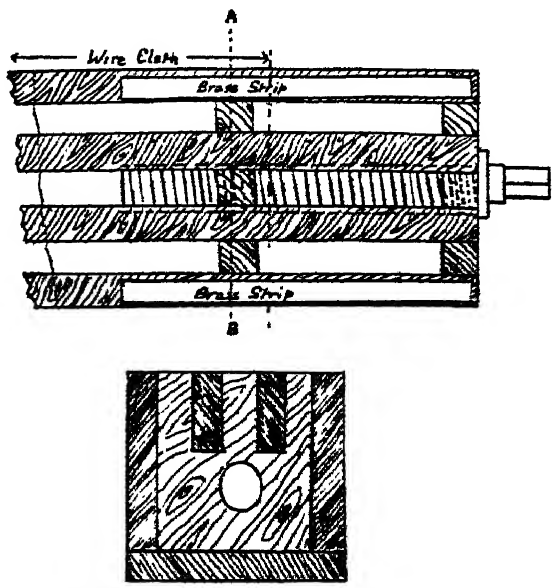


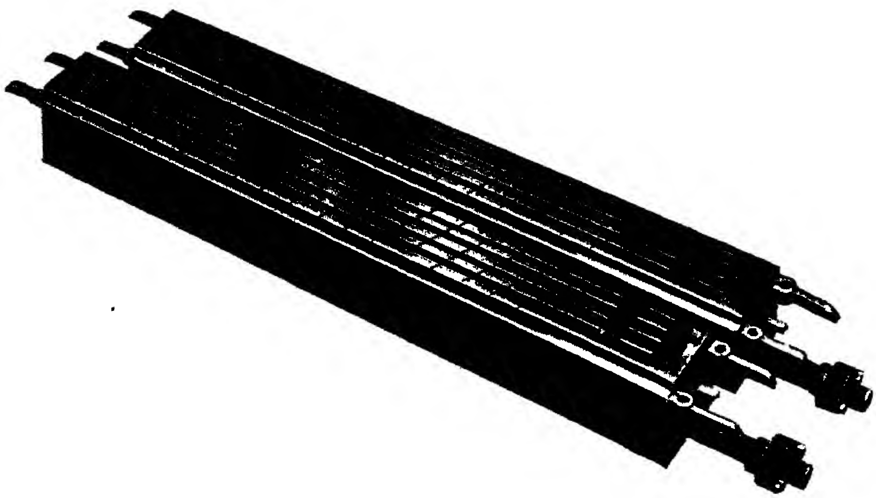
FIG. 65.—SUCTION BOX PLAN AND SECTION

The usual type consists of an air-tight, oblong box (Fig. 65), very solidly built of some hard, durable wood or brass. It is divided down the centre by an open frame, which supports one or more bars according to its width. The top edges and the bars are covered with very hard wood to take the wear of the wire. The bars are usually about $1\frac{1}{4}$ inches apart and should not be more, or the wire will be drawn down and over their edges. At the ends where the edges of the wire travel, brass plates a few inches in length are let in to take the wear of the rough edges. A pipe from the suction pump is connected to the centre of the box at the bottom or the side. Movable ends are provided to enable various widths of deckle to be followed. These are adjusted by a heavy brass screw extending through the outer end of the box. The box is made as rigid as possible, and is bolted and very firmly wedged in place on

the frame of the machine. Each box has a valve to regulate the suction admitted by the pipe, and a small pipe comes from the centre of the box to the fore side and is used as a fine adjustment for admitting air to the box. The space between the movable and fixed ends is kept full of water to prevent air leakage, and sometimes the suction may be kept more steady by, in addition, a packing of soft doctor broke.

There is another type of box, used chiefly on 'news' machines, which has one solid board forming the top. This board is drilled with holes or slits *en échelon*, and has movable ends of expanding rubber.

The ideal method of operating suction boxes is to have a separate pump



[*James Atherton (Sycamore) Ltd.*

FIG. 66.—NEW TYPE 'VULTURE' VACUUM BOX TOPS, WITH 'END ON' GRAIN FOR LONG WEAR
The top is in sections which can be easily fitted

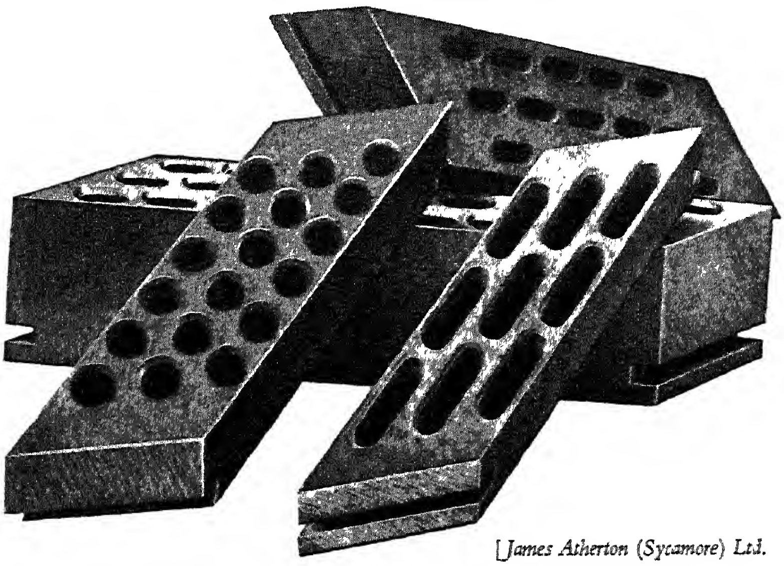
for each suction box. This is especially the case where other results besides the removal of water are required.

Where a dandy roll is used, it is absolutely essential that there should be a very fine control of the suction box immediately in front of the dandy. This is necessary even with a plain roll when it is important to get a fine, clear-looking sheet, but it is more important still when water-mark designs have to be put into the paper. The usual method is to have one suction pump for all the boxes, up to even five or six, and to rely on regulating the vacuum on one or two of the boxes, in order to control the sheet. This is not satisfactory, because the moment the vacuum is altered on one box it is automatically altered on all the others.

The suction pump attached to vacuum boxes has to deal not only with air passing through the sheet, but also with a large quantity of

water, and up till recently very little attention seems to have been paid to this point.

There is a tendency, however, nowadays for a large suction pump to be employed with a large receiver between the boxes and the pump. The bottom of this receiver has a drain-pipe leading to a water pump which draws the water away from the receiver as it enters from the boxes, and leaves the air pump to deal only with air, which is drawn out from the top of the receiver. By adopting this method a much more satisfactory vacuum is obtainable, and when the vacuum is altered on any one box it does not affect the others as readily.



[James Atherton (Sycamore) Ltd.

FIG. 67.—VARIOUS TYPES OF SECTIONS OF SUCTION BOX TOPS

There is also another method in which barometric legs or syphon pipes are used in the system for the withdrawing of water.

We are still of the opinion that to have infinite control over the sheet when making fine papers, *a separate vacuum pump to each box is desirable.* The chief difficulty, however, is to get a sufficiently small pump, which is so constructed that it will stand up to the long hours of usage necessary on a paper machine, and deal equally effectively with air and water.

Some machines still have steam ejectors on their vacuum boxes in place of air pumps, and these give excellent results, but they are extravagant in steam, and they are sometimes blamed for being responsible for making pin-holes in the paper. The least costly arrangement is to employ a barometric leg, and where the machine is built on the first floor and has a deep basement, it seems that there should be no difficulty in adopting this method, especially as the

vacuum required on a suction box is never very high, and where there are long runs on the same furnish with the same amount of water.

When a wire is being changed, all the boxes should be cleaned, examined and tested for loose or worn bars or protruding ends, and if necessary these should be carefully planed level, or changed by a man experienced at this work. All bars with hard, soft or damaged places, or with knots, should be discarded, as they will make ridges in the wire and cause loss of suction.

To obtain efficient and steady suction, the boxes must be carefully levelled to each other and to the last tube roll. The guide roll should be slightly lower than the last box, little more than the thickness of the wire; the latter will not then be dragged hard over the edge of the last box and the guide roll will have

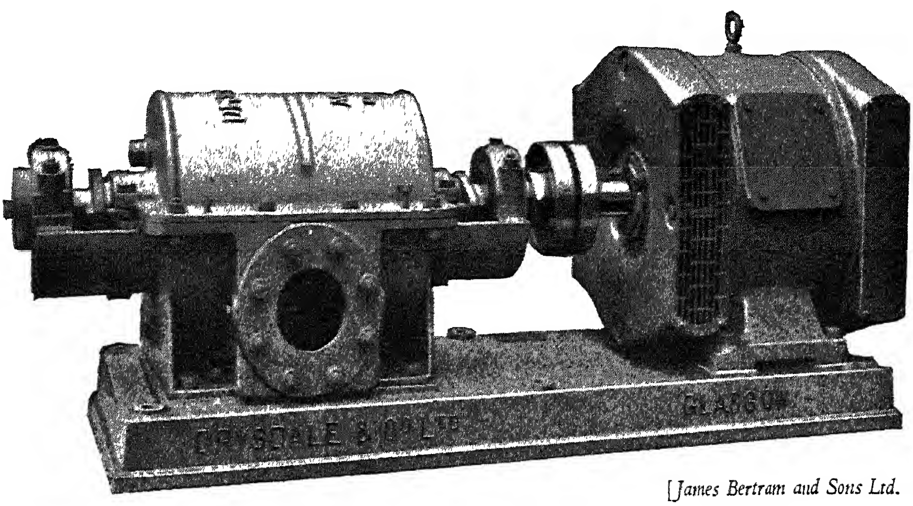


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FIG 68.—THE 'AQUAIR' VACUUM PUMP FOR SUCTION BOXES AND COUCH ROLLS
This pump is specially designed to deal with air and water

a good grip of the wire and have more control over it. Sufficient space is left after the first box to run the dandy roll; all succeeding boxes should then be as close together as possible.

The first box is the most important. It is often said: 'The first box makes the paper.' While this is far from being correct, there is no doubt that the appearance of the sheet is mostly controlled by the regulation of the suction on this box. Too much suction gives a cloudy-looking paper, too little a crushed or greasy appearance; in the first case, the water mark will be faint or absent altogether; in the second, it will be very muddled.

Apart from the first box, which has this special function, the other boxes should have the suction divided between them as far as possible, though in practice it will be found generally that one will stand more than the other.

If one box is being overworked, it will commence to vibrate with a hum-

ming or howling noise. This has the effect of upsetting all the others, as the vibration will have the same effect as putting very excessive shake on the wire, and the stuff will 'flood' into the couch. The boxes, after the first, should be very close together, so as to keep up a continuous pull on the web, one box taking it up the instant the other leaves off, and leaving little space or time for the water to rise again to the surface of the sheet.

It is often advised in making certain papers: 'Do not use too much suction.' But no one *can* use too much suction without causing the wire and boxes to vibrate. If the machine is making paper with the boxes not drawing up to their 'maximum', it means the machine is running too slow, unless held back by lack of drying power or other causes. It should be put up in speed so as to be able to make the paper, and no more, with all possible suction in use. Of course, wear on the wire is increased, *but so is production*, and a paper-mill is not run to keep a wire on the machine for a long time, but to get the greatest possible output of paper in the shortest time, and of the best quality. With regard to the latter, the drier the stuff can be made before it goes to the couch the more bulky and less wire-marked it will be. The couch-roll jackets and felts will last longer and the felts will not get dirty so soon. There will be fewer breaks at the presses and the whole work of the machine will be made easier. Therefore *in all cases* work your suction boxes, after the first, to the utmost limit of their capacity without vibrating them. Very often a good water-mark is crushed and made dull by the stuff being too moist when going into the couch rolls.

While dealing with suction boxes it should be mentioned that when a suction couch is in use, it is possible, and indeed often desirable, to leave much more water in the sheet after the last suction box than would be possible when a top couch roll is in use. The reason for this, of course, is that with a top couch roll, if too much water is left in the sheet, there is a risk of crushing at the couch. With a suction roll this trouble does not arise, and the excess water is removed satisfactorily by the vacuum of the suction couch roll.

Couch Rolls and Jackets.—The bottom couch roll is driven by the gearing and pulls the wire round. The top couch roll gives the first pressure which squeezes the pulp into the first semblance of a sheet of paper. The bottom roll is strongly built with a brass shell well stiffened with spokes and ribs. The top roll is greater in diameter and may have a brass shell or may be built of mahogany. Both rolls are, or ought to be, slightly *crowned* to work a certain weight at the spindle ends. Couch rolls are not set right on top of each other; the top roll sits well into the wire, for the reason that pressure of the wire against the circumference of the roll starts the pressure which culminates in the hard nip between the two rolls.

Though no water can be seen to be squeezed out until the nip is reached, there is no doubt that the pulp comes under the pressure sufficient to give it a certain stability and allow more weight to be put on the top couch roll. Most modern machines carry the top roll on swinging brackets, and levers for additional weights are attached to these. This is quite a mistake. More efficient couching can be obtained by putting the connections for the levers on the spindle itself so as to bring the line of pressure through the centres of both rolls as nearly as possible. Many machines do not use a cover on the bottom roll. This may not matter for cheap papers, where wire-marking is not considered of much consequence, but it is false economy where fine papers are concerned. A cover prevents crushing, gives more bulk and a closer under side, and does not obliterate the water-mark to the same extent as a bare roll does. This is accounted for by the increased pressure surface owing to the 'give' of the woollen cover.

When putting on a new cover, the roll should be thoroughly cleaned with hot water and the perforated holes in the shell cleaned out. If the water has been hot enough the roll will soon dry, or it may be wiped dry with a clean rag. The end over which the cover has to be drawn requires special attention, lest any bit of stuff or grease or chip of wood from the wooden end be pulled in and thus make a lump inside it. The cover should be temporarily fixed at the front side. It must then be pulled tight to the back side and permanently fixed there. The front side is then loosened and also pulled tight and permanently fixed. Whether it is tacked on to the wooden ends or roped on, it should be free to travel round the roll. Boiling water is necessary for the proper shrinkage of a new jacket, and quantity should not be stinted. If the cover has a nap—though this is not a necessity for a bottom roll—it should be in the running direction of the wire, so that the drag of the latter smooths out the fibres instead of ruffling them up. Sometimes a cover is tight and difficult to pull over the roll. Powdered starch or dry china clay well rubbed over the roll will help to make it slip on more easily. But if this happens often the manufacturer should be notified and will be able to correct the size. After the cover has been shrunk, it is very necessary to go all over it carefully with the fingers lest there should be any hard knot in the wool or any substance underneath. Hard knots and wood splinters are not uncommon in covers and should be picked out with a sharp-pointed knife. Neglect of this precaution means a ridged wire in the space of an hour's work. This applies to both coucher covers.

It will greatly assist the starting of a new top jacket if the nap is gently brushed the running way, more especially on the two places where the jacket has been folded, and which have a tendency to stand up. If the covers are

tacked on to the wooden ends, the latter must be perforated to allow the escape of the water coming through the perforations of the shell, and holes correspondingly punched in the covers. If roped on, the water will find its way through the open folds between the stitches. It sometimes happens that a cover works over one end of the roll. This may be owing to weight being applied unequally on the levers, insufficient shrinkage, or to the cover not having been pulled tight from side to side. If correcting the weights does not send it back again, the best remedy is to loosen the tacks and refix, or put in a fresh rope, tighten up and apply hot water to the rope. Rope for this purpose can be obtained which tightens up and remains tight with the application of moisture, and roping is the quickest and safest method of fixing. When first put on, the coloured line of the cover will be approximately correct across the roll, but later on will show a bend in the centre. This is to be expected from the slight crown of the roll and the fact that the wire is tightest in the centre. But if one side should take the lead a little there is no cause for alarm. It may be that the guard board is not so hard down, or so well fixed, or the inclination of the couch rolls may not be exactly correct at both sides. The roll may be more smooth at one side than the other, or the weights unequally adjusted. If all arrangements are fairly accurate, the difference in the line will be very slight, and will only go a short distance and may be discounted. But if the line continues to go farther off the straight, the machineman may be sure that some one or more of his adjustments are seriously wrong, or the inclination of the two rolls requires skilled attention and correction from the engineer.

In starting up with a new top jacket, unless the stuff is very 'free' and can be well dried at the suction boxes, it will be found that the new nap picks up fibres from the sheet. These accumulate until a small, flat patch of pulp is formed, and a new jacket may be covered all over with these patches in a few minutes.

The best remedy is to have the guard board well adjusted and hard down at the start. (It should be eased off again as soon as the jacket has become 'seasoned'.) The suction should be used to the utmost and as little weight as possible put on the roll. If the cover is run for a few minutes before starting up, with a hot mixture of resin size and china clay in the water channel of the guard board, there will be less trouble of this sort. Where it is possible, warm water, in place of cold, should be used in the water channel to clean off the patches of fibres.

In any case, it is best to start up with a new jacket at a speed slow enough to have a good control of the stuff at the suction boxes, and the wire as tight as safety permits.

Many machinemen prefer to run an hour or two with no water on the cover until it fills up to a working condition.

At all times it is inadvisable to rub the hair or nap of the jacket the wrong way if the stuff shows signs of going up the roll. Only a momentary improvement is obtained. A hot and strong solution of soda ash is far more effective, and this should be used when the cover requires cleaning, instead of using the force jet. As one of the chief causes of wear in a cover is the plucking out of the nap by the meshes of the bare wire, the new cover should, if possible, be started with a full-width deckle and full widths should also be run as long as can be arranged.

The Guard Board.—The function of the guard board is to clean and dry, as far as possible, the cover of the couch roll. As pressure is the integral part of this action, it will be readily recognised that its use will be the chief factor in shortening the life of the cover. For this reason various kinds of appliances have been tried, and many ways of fixing, pressing and covering the rubbing edge of the board have been resorted to. We will not go into details of these, or the special designs applied to high-speed machines, but confine ourselves to the types that are commonly used for machines in general. A guard board is usually constructed from one piece of good wood (pitch pine), strengthened and made rigid by another piece at right angles, fixed at the back of the board; or in some cases this is replaced by a rod of iron used as a 'stringer'. It is covered on the rubbing edge by a piece of old couch cover, and there are two ways of fixing and using it. It may be fixed to the brackets which hold the couch roll, sliding in a guide, and being pressed down by springs; sometimes there are no springs, and the board is pressed down by hand and fixed in position by bolts. If the brackets are of the modern type which swing with the couch roll, the board will of course rise and fall with the roll; but if the brackets are of the older fixed type, the roll is apt to lift the board and let water pass.

A board of this kind must be very carefully used. The machineman is sometimes tempted, when running very wet or fine stuff, to squeeze it very hard down on the cover, when he may very easily reduce the life of the latter by half. A safer and more efficient type is the swinging board. This is hung on pivots on the brackets and the pressure is applied by weights hung on short fixed levers on the back of the board. Being free to rise and fall, it does not require to be so heavily pressed on the roll, and the pressure is more easily controlled and observed. This kind, owing to the angle at which it touches the roll, has the advantage of allowing a deeper flow of water to be used to clean the cover, and therefore washes away any fragments of fibre that may come up the roll. A fixed board requires to be set opposite the point of pressure of the couchers, and the angle admits of a very shallow flow.

The board may be used without a cover, but though the wear of the jacket is less and the joint is more water-tight, the jacket fills up with size, loading and fine fibres, and requires frequent cleaning and blowing with the force jet. The efficiency of the couch roll is greatly reduced, and any saving in covers is nullified by the waste of time and extra 'broke'. The flow of water is

[*Robert Fletcher and Son Ltd.*

Fig. 69.—Suction Couch Roll working on a Machine making Fine Tissues at High Speed

supplied by a spray-pipe close to the guard board, but the spray must not play on the couch-roll cover, or it will raise the nap and the fibres will be pulled off by the board. A frequent cause of damage to the cover is that, when shutting down or starting the machine, bits of pulp or foreign matter stick to the roll, and become jammed in the board, cutting or scoring the cover in

a few turns, or, passing the board in hard rolls, spoil the wire. Brushes or strips of old jacket are sometimes fixed in front of the guard board to loosen these and allow the water to wash them away.

A very good combination is a swinging board and a rubber-covered squeeze roll just after the couch roll clears the board. Then the board may be used as a light cleaning agent and the roll will take the water out of the cover before it touches the paper, far more effectively than a board can. With this arrangement higher speeds and more output can be obtained, without the necessity of increasing couch-roll weight.

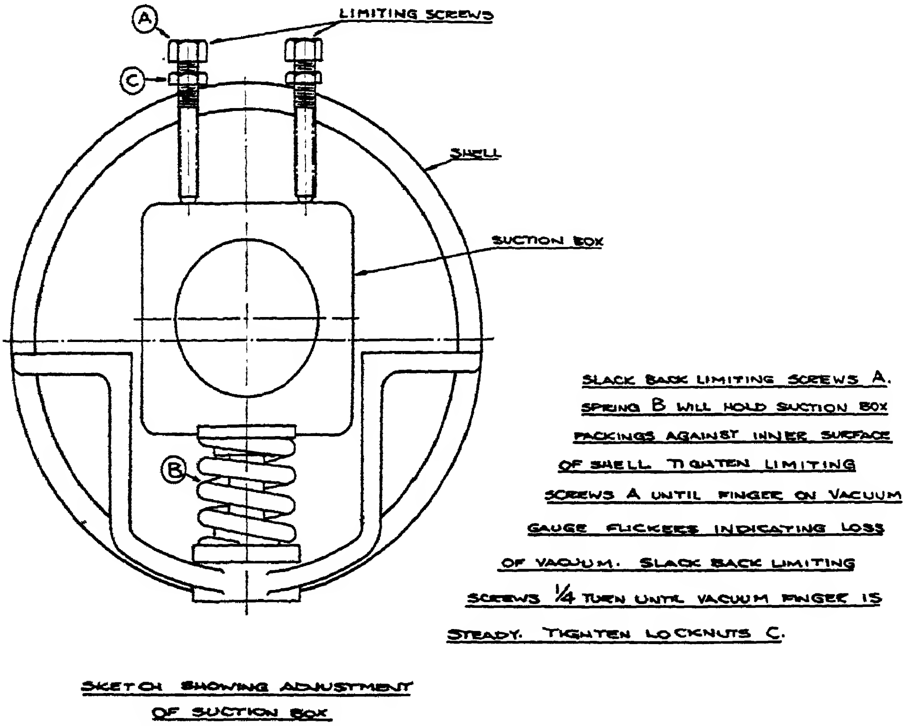


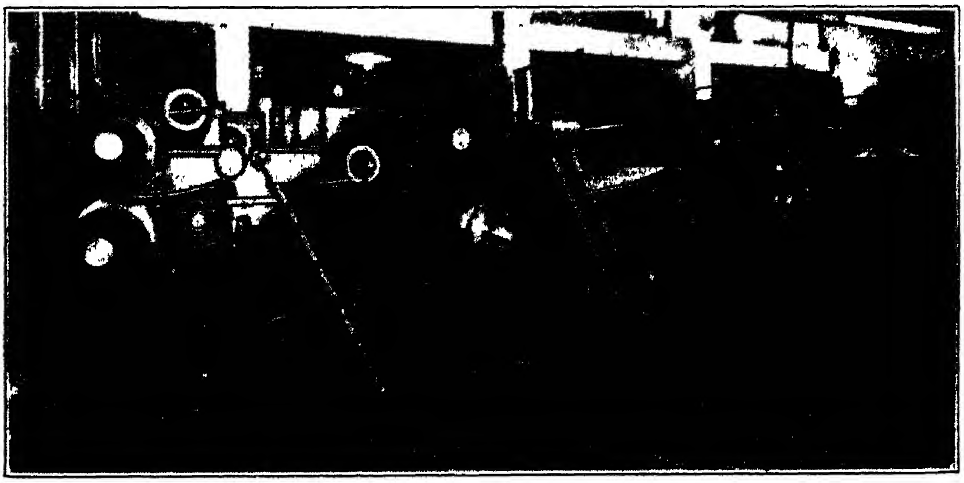
FIG. 70.—MILLSPAUGH SUCTION ROLL, SHOWING SPRINGS FOR HOLDING BOX UP TO SHELL AND ADJUSTING SCREWS

Suction Couch Rolls.—The suction couch roll (Fig. 69) has now almost superseded the couch press, and although some people still use the press method of couching, it seems that the suction roll will soon be universally employed.

The suction roll has many advantages over the plain couch, the chief of which is that there is no top roll and no jacket. The eliminating of jackets saves a great deal of time, and a great deal of spoilt paper, because jackets always gave some trouble when starting up new, and further trouble when becoming worn. The elimination of the top roll has entirely done away with crushing of wet stuff, and the damage done to the wire by the pressure of the nip, due to lumps of stuff or foreign matter, has entirely disappeared.

The guiding of the wire is much simpler and, in fact, presents practically no difficulty with a suction roll, and the danger of running the wire out of square, due to uneven weights on opposite sides of the couch press, does not arise when a suction roll is used. Much longer life is generally obtained from the machine wires, and in most cases a drier sheet is delivered on to the wet felt, which latter in turn naturally has a longer life, by reason of the fact that it has not so much water to deal with.

There are now several very satisfactory suction couch rolls available, and experience seems to show that they will run for many years without any attention whatsoever. While some of these rolls consume a fair amount of power through their vacuum pumps, very efficient pumps are now available, and the power consumed is nothing when compared to the efficiency of the roll and



[*Walmsleys (Bury) Ltd.*

FIG. 71.—THE PRESS PART OF A MODERN MACHINE: PLAIN PRESS ROLLS

its many advantages in the saving of time and the maintaining of production at a high level.

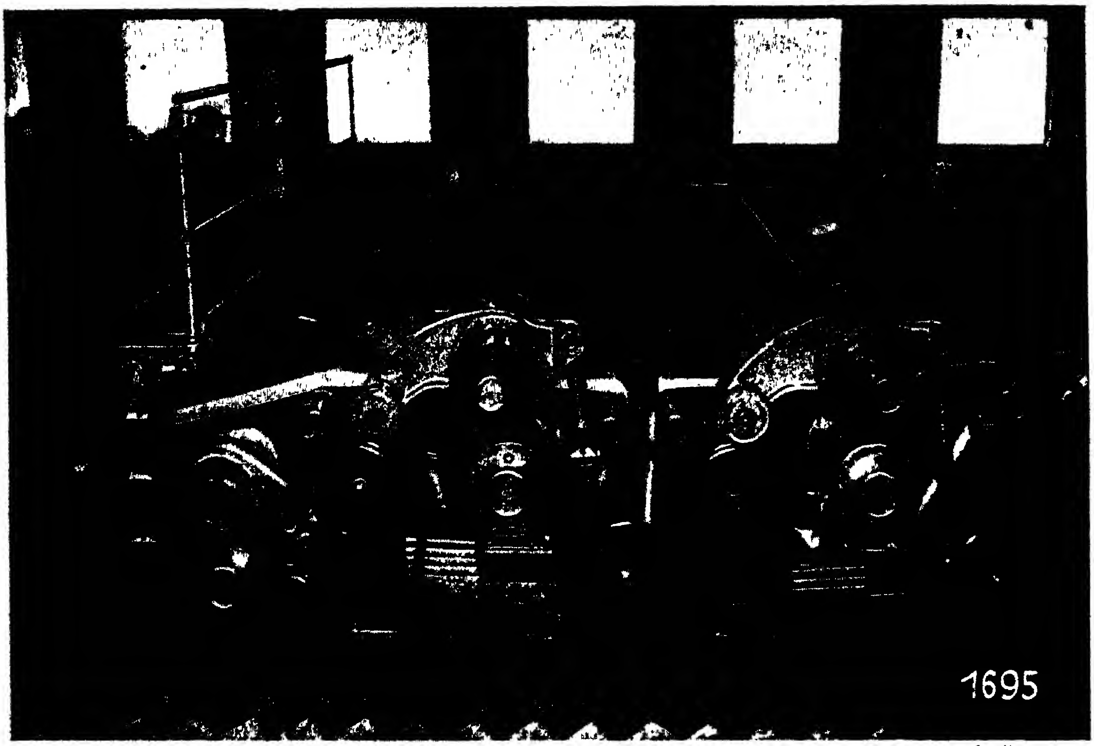
Presses.—After passing through the couch rolls, though the sheet is now, for the first time, in condition to be handled, it must be further pressed, so as to be so far freed from water as to stand the heat of the dryers.

This is accomplished by running it on woollen felts between 'press rolls'. Two sets of press rolls and felts are used, though machines designed for high speed or for making special papers may have three or four. Since pressure means loss of bulk, it is not desirable for machines making high-class paper or bulky printings to have more than two sets. The first set of press rolls and the 'wet felt', as it is called, do the bulk of the work. The second set is so arranged as to smooth out the wire mark.

Underneath the bottom roll is placed an oblong box or tray to catch and

lead away the water squeezed from the web. The bottom roll is driven and the pressure of the two rolls pulls the felt round. Before the felt and paper enter the nip there are often air pockets between them. A small suction box with perforated holes on the top is arranged at this point and extracts the air so that no wrinkles are formed in the paper. Sometimes, a roll of 2 to 3 inches diameter, called a 'blow roll', is used to raise the paper from the felt and allow the air to escape.

Of late years, press rolls of granite have become popular. The cold, crystalline surface does not pick up 'greasy' or fine stuff as easily as the brass shell



[*Füllner*

FIG. 72.—WELL-ARRANGED PRESSES ON A MACHINE FOR MAKING FINE TISSUES

does. For this reason they are valuable for use with esparto, straw, and mechanical fibres, which have very little strength or length to carry them over the machine. They are usually run with non-metal doctors to obviate 'pencilling'.

The top press roll may be made of iron, brass, granite, or wood. The bottom roll is usually rubber-covered. Sometimes two brass rolls are met with, but these are very destructive to felts, since a small lump passing through will cause the felt to be damaged. The rubber covering of the bottom roll lessens this danger considerably. With a rubber-covered roll there is a less severe nip of the felt and paper, but even so quite satisfactory removal of water is effected and longer life obtained from the wet felts. The

top press roll is fitted with a doctor, either iron or composition, the purpose of which is to clean the roll and also to hold up the stuff which may stick to the roll, and prevent the sheet from going round if a break occurs.

Suction Presses (Fig. 73).—The tendency is nowadays for the ordinary press to give way to the suction press. This press consists of a bottom roll containing a suction box and perforated shell, which is the same as the suction couch roll, with the exception that it is usual for this suction roll to be rubber covered over the bronze shell. Where suction presses are used, it is not generally found

FIG. 73.—RUBBER-COVERED SUCTION PRESS ROLLS [*Millspaugh*

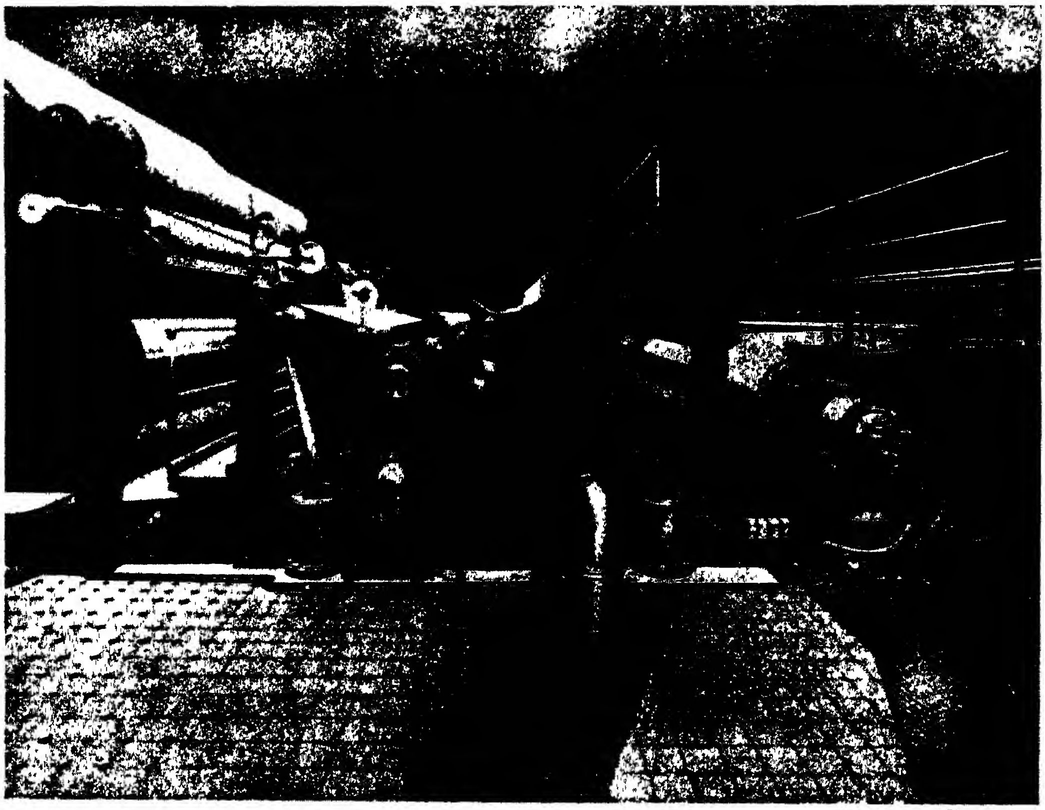
necessary to have such a heavy top roll, or to use such pressure, as was often found necessary with the ordinary press. Some paper-makers maintain that if they had the option of having a suction couch or a suction press, they would prefer the suction press. The reason for this is that all felt troubles are practically eliminated, very much longer life is obtained from the wet felts, very even drying of the paper results, and a much more uniform sheet is obtained. It is usual to have 14 to 24 inches of vacuum in the suction roll, and the hardness of the rubber used varies between 30 P-J. and 50 P-J., the first being comparatively hard, and the second much softer.

The Dual Press (Figs. 74 and 75), which is now being taken up in this country, has actually been in use for some years in America.

It consists of three press rolls, two of which may be suction rolls, with a plain roll in between, as clearly shown in the photograph and drawing.

There is a great saving in space with this arrangement, but there are also many other advantages claimed by those who are using this design.

The pressure is applied laterally by levers, instead of vertically, and much greater felt life is being obtained.



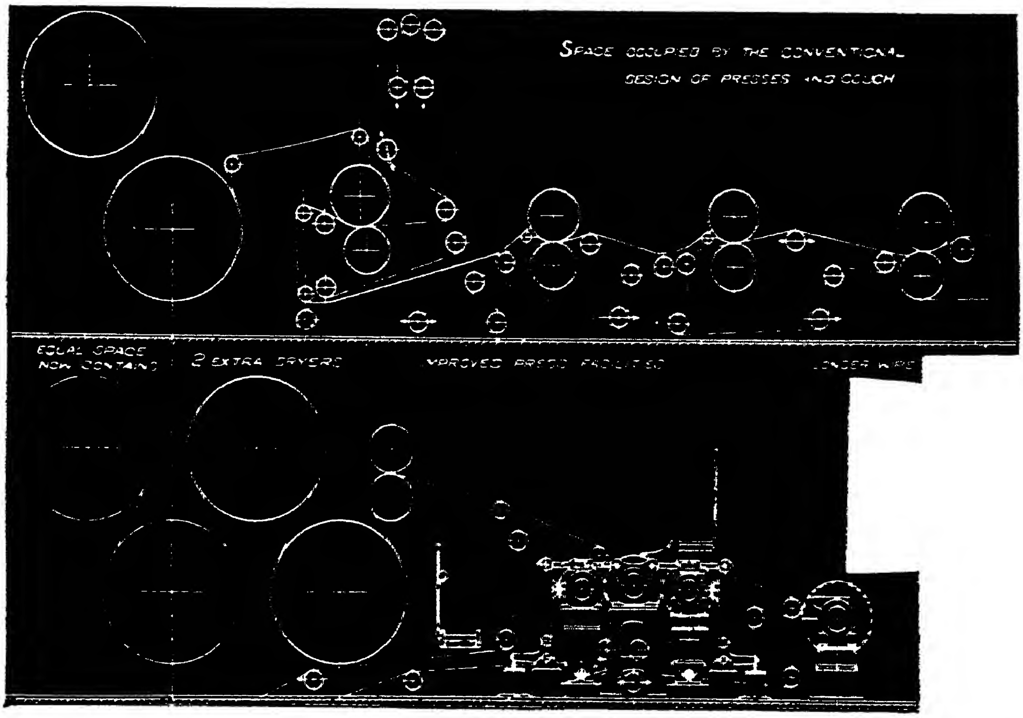
[*Walmsleys*

FIG. 74.—DUAL PRESS ARRANGEMENT, SHOWING ONE SUCTION ROLL AND TWO PLAIN ROLLS ARRANGED TOGETHER
The third roll can be arranged for suction if necessary

A doctor blade should be made to move from side to side by traversing gear; the purpose of this is to prevent pencilling or scoring of the roll by any particle of grit becoming embedded between the doctor blade and the roll. The doctor is hung on pivots to enable it to be cleaned and refitted.

The felts are pure wool fabrics and may be obtained from the makers in many degrees of fineness and quality. Nevertheless, it is sometimes very difficult to find a kind that is both efficient and economical to run, owing to

peculiarities of the machine, the speed, the quality of the stuff and the system of cleaning, etc. One of the questions that is being continually asked by paper-makers of each other is: 'How long do your felts last?' Conditions vary so much that the answer may be either ten days or ten weeks. To illustrate this, suppose we are making a well-fibrillated bank at from 100 to 150 feet per minute. We will perhaps find that we can have little pressure on the coucher at, say, 120 feet, and still less at 150 feet. Then the sheet will enter the press rolls with a higher percentage of water. This is throwing more of



[*Walmsleys*

FIG. 75.—SKETCH SHOWING USUAL ARRANGEMENT OF PRESSES (ABOVE) AND DUAL PRESS (BELOW)
The saving in space is very considerable

the work of water extraction on to the felt, not only by increased speed, but in quantity, greater in proportion to the ratio of speed. In addition, the increased speed reduces the efficiency of the rolls and felt. The forward impetus of the water carries it through the rolls in greater quantity. The time factor of the nip is reduced. The water flowing through the felt and running down the bottom roll has less time to get away and remains nearer the nip. The porosity of the felt, though actually unaltered, is less able to allow of the extra water getting through. The pressure of the nip must, if possible, be increased to keep the paper relatively as dry as at the lower speed.

Consequently, the felt will get 'dirty' in a shorter time and require more drastic cleaning. In this case we must reckon the life of the felt on the *quantity of water extracted* as well as on the weight of paper made and the time run. Conversely, with free beaten stuff and a heavier substance that can be well couched, we may easily make ten times the weight of paper without being checked by felt-crushing. Then there is the question of felt-cleaning. The simplest plan is to run a felt until it gets dirty and replace it with a clean one. The felt is then washed on a felt-washer and put back again in turn. The chief objection to this system is the waste of time changing felts. Another plan is

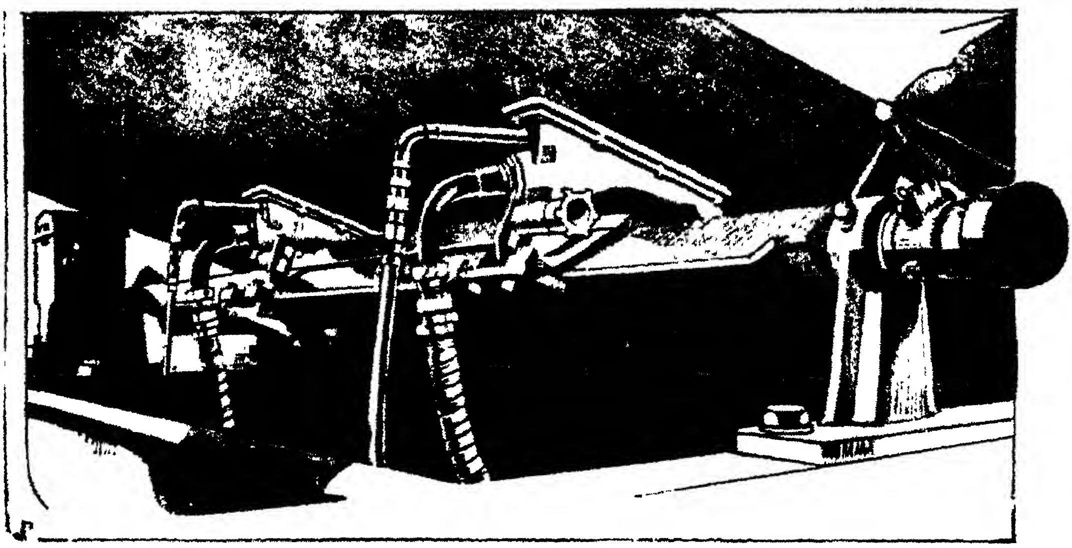


FIG. 76.—VICKERY FELT CONDITIONER WITH TWO SHOES [*Vickerys*

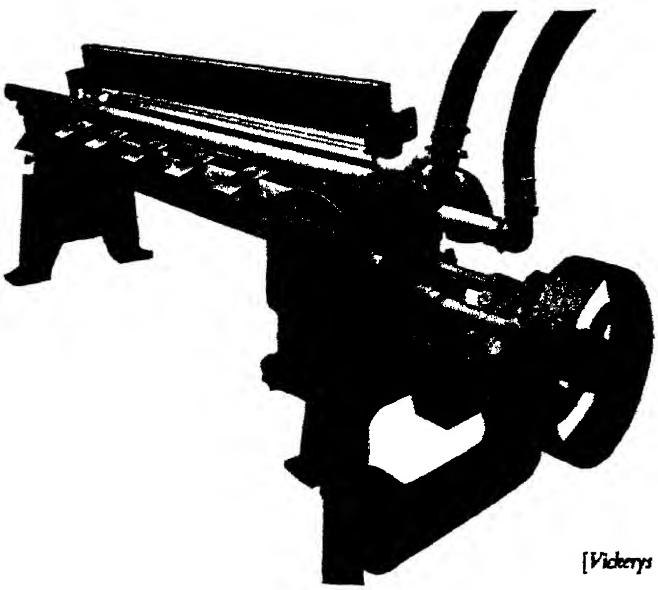
to shut the machine and clean the felt without taking it off. This also is time-wasting and really only saves labour in changing felts, since this latter operation could be done almost as quickly as washing on the machine.

Felt-washers operating on the machine as the paper is being made offer a solution of the problem, but are open to the objection that the continual washing wears out the felt as much or more than the legitimate work does. The usual felt-washing apparatus on the machine consists of a series of sprays impinging on both sides of the felt, a pair of rubber-covered rolls to press out the dirty water, and a small suction box to dry the felt again ready for the paper.

The Vickery felt conditioner (Fig. 76) is the best attempt to solve the felt washing problem, and is now in general use. It may be made very drastic in its action and requires skilful and careful manipulation, since, of course, any

means of raising the nap and cleaning it by suction is bound to be more or less destructive.

The Vickery Adjustable Friction Type Felt Conditioner.—This is an improved type which has recently been introduced, and whereas in the case of the standard conditioning unit the felt is drawn across the fixed top of the box, so creating friction and consequent wear, in the case of the adjustable friction type the box is divided into three suction chambers, the first and last of which are operated at a very low vacuum, while the centre chamber is operated at a higher vacuum.



[*Vickerys*

FIG. 77.—FELT CONDITIONER DESIGNED FOR MOULD AND BOARD MACHINES

Friction between the felt and the conditioning unit is reduced to the minimum necessary for efficient conditioning by means of revolving members in the box itself, and travelling bands at each edge which carry the felt across the face of the box.

Further, there are means for adjusting the degree of scraping action on the face of the felt.

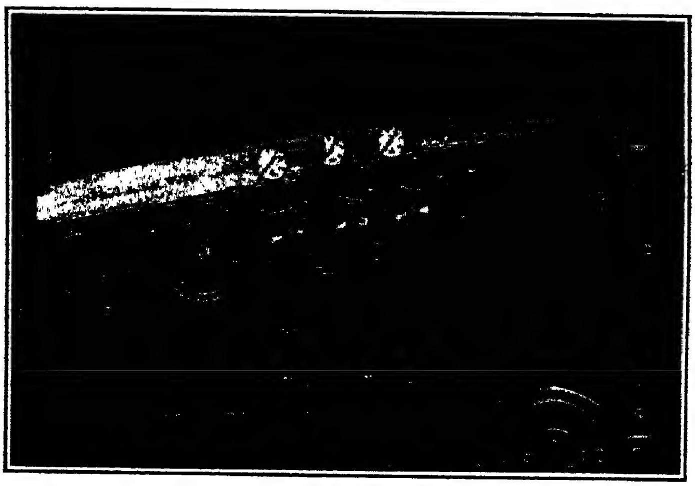
Some installations which have already been made show a remarkable increase of efficiency and an increased felt life averaging up to as much as 50 per cent.

The suction roll is now quite commonly used as a wet-felt cleaning device. Usually it is made smaller in diameter than the suction press roll. To get

the best results the wet felt should be carried well round the roll, and there should be a strong spray of clean water directed on to the felt immediately before it goes to the roll. A very high vacuum is required in order to dry the felt sufficiently to enable it to take up moisture from the paper when it returns to the press. The chief advantage of this type of cleaner over the travelling type is that it leaves the felt in the same condition right across the machine.

The Evans Rota Belt type of suction box (Figs. 78 and 79) was originally introduced to take the place of the fixed-top suction boxes under machine wires, but it did not meet with very great success in the early days.

It was then developed for use under wet felts, in which position it has thoroughly justified itself and become firmly established as an excellent means



[*W. P. Evans and Son Ltd.*

FIG. 78.—THE EVANS ROTA BELT, WITH THREE SUCTION BOXES, FITTED BENEATH A WET FELT

of drying the wet felt, preventing blowing, and generally improving the performance of the press rolls, besides increasing considerably the life of the wet felt.

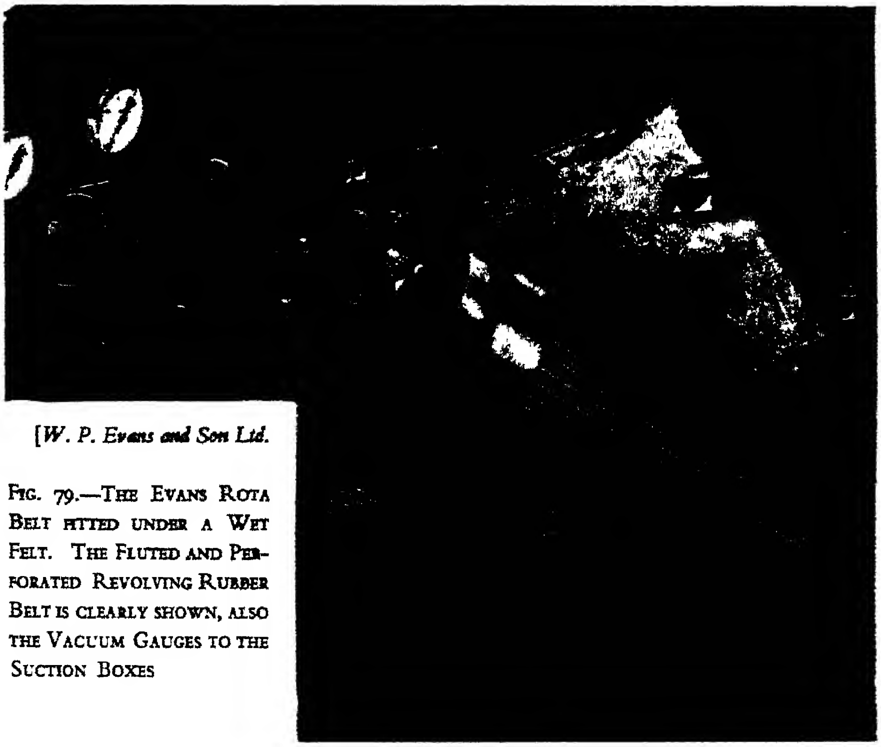
It has been considerably improved lately, and is now being used with success in place of the fixed-top suction boxes under the machine wire.

It consists of suction boxes, usually in sets of three, each of which can be individually controlled. Over these a grooved and perforated endless rubber belt passes, driven through friction with the under side of the wire.

The vacuum in the boxes draws water through the belt, and delivers it to the backwater system in exactly the same way as the ordinary suction box.

The chief difference between an ordinary suction box and an Evans Rota Belt lies in the fact that the wire, instead of having to be dragged over hard wooden or metal box tops, passes over the soft rubber band, which is moving at the same speed, and therefore there is a tremendous saving in the friction and consequent wear on the under side of the wire.

The advantages of this will be quite obvious, and it is this saving in friction which was the chief reason for the introduction of the belt in the first place.



[*W. P. Evans and Son Ltd.*

FIG. 79.—THE EVANS ROTA BELT FITTED UNDER A WET FELT. THE FLUTED AND PERFORATED REVOLVING RUBBER BELT IS CLEARLY SHOWN, ALSO THE VACUUM GAUGES TO THE SUCTION BOXES

It seems that this belt will now stand up well to the severe conditions of modern paper machines, and that it may soon have universal application both on felts and wires.

When passing through the first press, the paper, being very moist, takes the impression of the cross-meshes of the felt fabric. In Drawing Cartridge this is called the 'tooth' and is a distinctive feature required and expected by artists and draughtsmen. Coarse mesh felts, specially made for the production of various varieties of tooth, may be obtained from felt-makers, and this paper is made in imitation of 'hand-made drawing'. For 'fine' papers, such as writings, banks, ledgers, etc., and body paper for coating and printing, the felt marking is very undesirable, as it prevents a close finish being obtained. The

second press is designed chiefly for eliminating felt and wire marks. For this reason the rolls run in the reverse direction to the first press, and the paper is reversed, so that the under side, which is impressed by the wire and felt, is made to come in contact with the top roll of the second press. This has the effect of greatly reducing this fault, and as the second press is seldom pressed hard, the paper is made more equal-sided for the reception of finish.

Second press felts are seldom washed as they run, but are kept in condition by washing with the force jet at every opportunity, or changed for washing on the felt washer. Although the second press does not often cause crushing when the felt is dirty to the same extent as the first press, the felt must be kept in very good condition. When it becomes the least bit clogged up, it affects the drying of the paper, and is one of the chief causes of 'cockles' and other drying troubles.

When a new felt is put on a machine it requires to be thoroughly wetted with cold water, in order to shrink it to its running tension. If this is not done, it will begin to tighten up soon after the wet paper is run over it.

The tension has to be regulated to give the greatest porosity to the felt. If it is too tight it may run into wrinkles, and be less porous owing to the meshes being pulled together. If too slack the meshes will not be opened up and the felt will very quickly become dirty. The coloured line or lines must be kept straight across the machine for the same reason, and the nap should be in the running direction, both on the machine and on the felt washer. All rolls require to be true and perfectly parallel, as a felt is very difficult to run if any one is not correct. Spiral felt rolls help to keep the felt free from wrinkles and the meshes open.

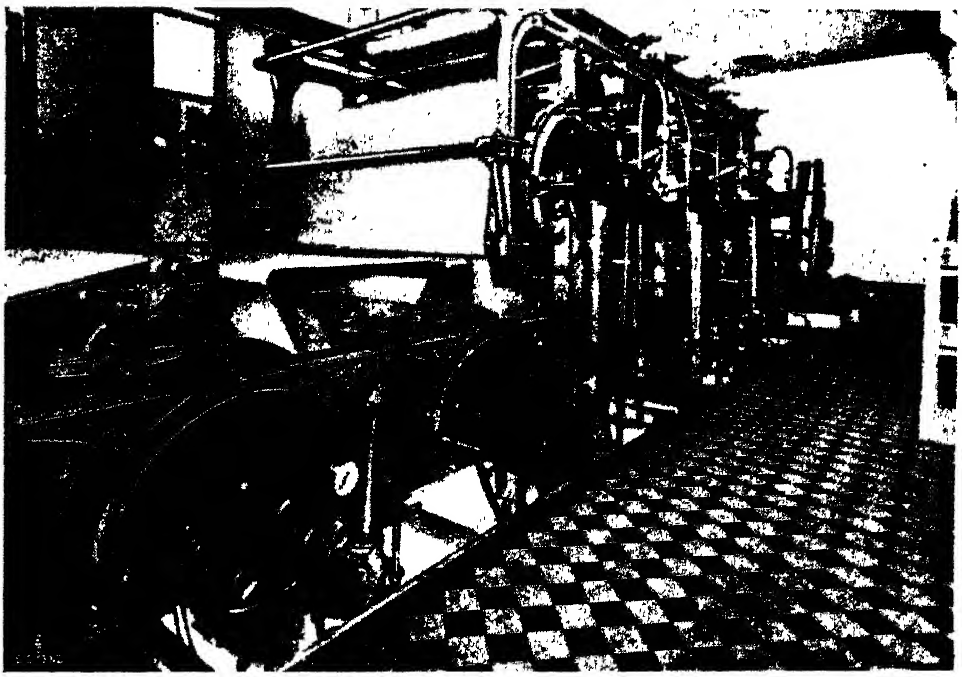
Although it is very desirable to run felts as long as possible, it should always be borne in mind that it is far cheaper to dry paper by the press rolls and felts than by steam in the drying cylinders.

Apart from the loss through breaks and bruised sheets, caused by trying to get an additional week or two out of a worn felt, the addition to the coal bill will be very great, but this is unfortunately very often lost sight of, or it may even be entirely overlooked. The use of felt rolls covered with vulcanite is recommended, as the surface of the vulcanite is 'kind' to the felt, and gives it a longer life.

The Drying Cylinders (Fig. 80).—Having pressed as much water out of the sheet as possible, there is still anything from 64 to 72 per cent of water to get rid of. (See Appendix.) This is accomplished by running the paper over steam-heated cylinders, on to which it is pressed by dry felts. The cylinders are of cast iron with highly polished surfaces and may be from 3 feet (on old machines) to 6 feet in diameter. Steam is admitted to the cylinders by various

types of pipes and glands. The most modern comprises the inlet pipe and the condensed steam pipe, or outlet pipe, arranged to enter the cylinder together through the hollow journal at the back side, so as to avoid having a pipe at the front side. This gives more freedom in leading the paper through and in putting on new felts. Formerly the inlet pipe entered at the front side and the outlet pipe at the back.

Inside the cylinder it is necessary to have some arrangement for getting rid of the water formed by the condensation of the steam. This takes the



[*Siemens Schuckert*

FIG. 80.—ARRANGEMENT OF DRYING CYLINDERS ON A MACHINE MAKING FINE PAPERS
Each cylinder is driven by a separate motor

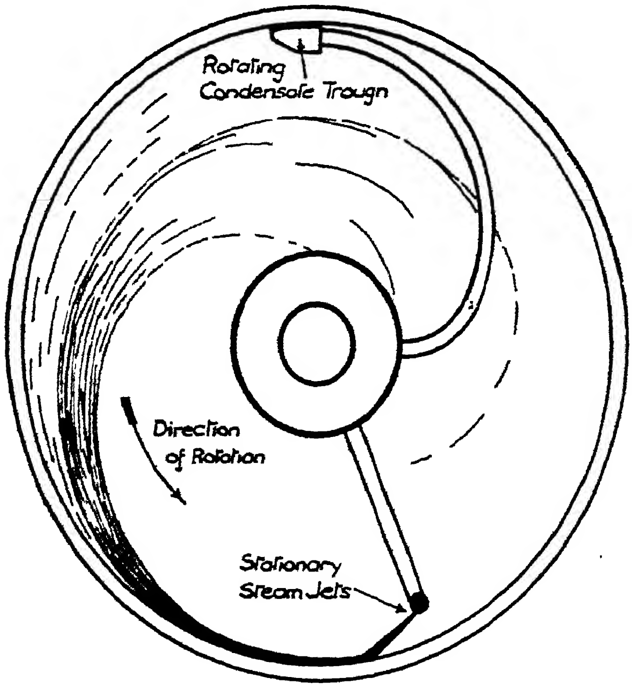
form of a bucket or chute attached to the end of the cylinder, which scoops up the water and raises it to the centre level, when it runs away through the outlet pipe. A syphon pipe is often used, the outlet pipe being carried to the bottom of the cylinder.

The pressure of the steam forces the water up and out. In the case of cylinders 5 feet in diameter, at a speed of 490 feet per minute, centrifugal force carries the water round the cylinder wall, and both these types become inoperative. Each cylinder should have a separate steam trap, to prevent loss of steam by the steam blowing straight out through the outlet pipe. The simplest steam trap is similar to a water cistern. A floating ball opens and

closes a valve in accordance with the quantity of water coming through the pipe. A great many varieties of steam traps have been put into use of late years, but they all work on much the same principle, and, unless kept in good order and regularly cleaned out, are more often than not steam wasters.

Steam and water nozzles without packing are now in general use. The principal feature of these nozzles is the total absence of packing, all the joints being carefully machined, and there is an ingenious system of lubrication by which these joints are kept covered with a thin film of oil, which reduces the friction to a minimum and keeps them both steam- and water-tight.

There are special patterns for drying cylinders, machine and supercalenders, M.G. cylinders and boilers, and they are made for functioning with either water lifters or syphons.



[Bentley and Jackson

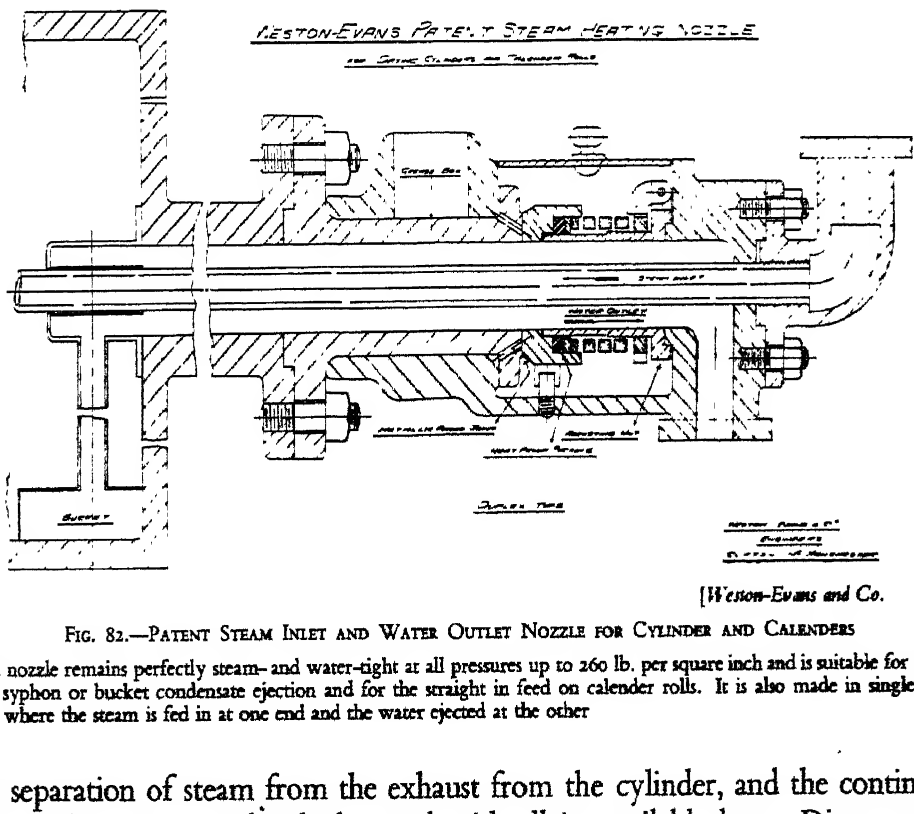
FIG. 81.—DIAGRAM OF STEAM IN THE DRYING CYLINDER, AND CONDENSATE COLLECTING TROUGH

On a machine where the cylinders are few and constantly in use, the outlet pipes may all be connected to one large pipe and one long steam trap. But the objection to this is that the steam blows back and overheats those cylinders that are not required to be very hot, as it is not advisable to have stop valves on the outlet pipes.

Steam Circulation Plants.—The old method of trapping the steam from each cylinder or section of cylinders has now almost entirely given way to a new method of steam circulation. There are two plants in use, the V.J.B. steam circulation system and the Holmes and Kingcome. The principle of the V.J.B. is that it injects steam into the cylinder, traps that steam when it leaves the cylinder, separates it from the water, and reinjects the uncondensed steam again into the cylinder, thus ensuring that all the latent heat of the steam is made use of in heating the cylinder, and until condensed water passes away through the trap to be returned to the hot well.

Very large savings in coal have been effected in many mills by the introduction of this system, together with vastly improved drying on the paper machines.

The British V.J.B. Three-Stage Steam Circulation Heating System.—The simple method of heating cylinders by blowing in steam, and after it has passed on some of its heat, exhausting the condensed steam through a steam trap, has two disadvantages: First, rather a long time is required in which to drive out the cold air from the cylinder to be heated; and, second, there is much inevitable wastage of steam through the trap. The original V.J.B. circulation system was designed to eliminate these faults. Provision of sufficient cocks in the system and skilful design of piping enabled the air to be rapidly released from the cylinder to be heated, but the main feature of the system lay in economy of steam consumption. This was effected



[*Weston-Evans and Co.*

FIG. 82.—PATENT STEAM INLET AND WATER OUTLET NOZZLE FOR CYLINDER AND CALENDERS

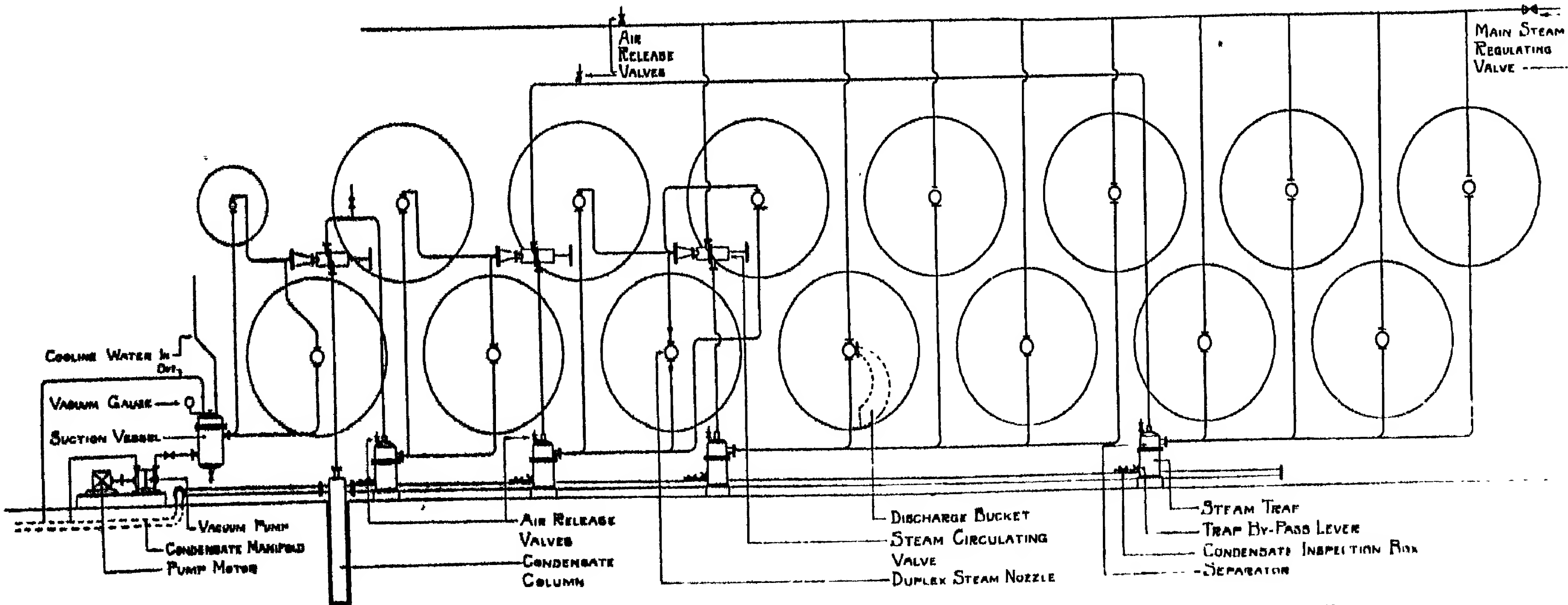
This nozzle remains perfectly steam- and water-tight at all pressures up to 260 lb. per square inch and is suitable for either syphon or bucket condensate ejection and for the straight in feed on calender rolls. It is also made in single form where the steam is fed in at one end and the water ejected at the other

by separation of steam from the exhaust from the cylinder, and the continued use of this steam until it had parted with all its available heat. Direct steam was not blown straight into the cylinder, but was passed through an ejector, which drew the exhaust steam from the trap, so using a mixture of fresh and reduced pressure steam for heating. Steam entering a cylinder was constantly being drawn out and put back again, through the ejector, until it had parted with all its available heat and become condensed. The two essential features of the system were the steam trap, which incorporated a separation chamber for the steam, and the ejector, which relied upon steam for its operation.

The improved British V.J.B. three-stage steam circulation heating system retains these two important features in unchanged form, but uses a different cycle of operation. The extravagant feature of the original system lay in the fact that the same temperature was attainable on all cylinders, and most economical working was effected only when such conditions obtained. When the last cylinders were required very hot and the first cylinders only just warmed, the system suffered by the recirculated steam cooling the direct steam, its original temperature never being fully utilised in the cylinder. In the latest British V.J.B. three-stage steam circulation heating system, heating is done in three separate stages, enabling still greater economy to be effected by the more complete use of the heat of the steam.

The three stages are: *First*, the heating stage, which consists of the cylinders using direct steam, undiluted by steam under reduced pressure, to heat the cylinders requiring the highest temperature. *Second*, the mixed stage, consisting of the cylinders using the exhaust steam from these hottest cylinders mixed with direct steam. This stage is very important, because, according to the quality of the paper, the cylinders can be heated to any required temperature, high or low, thereby making the whole system very flexible. The *third* or suction stage is divided into two groups: first, the cylinders receiving a mixture of exhaust steam from the mixed and heating stages; and the second group, which receives the steam evaporated from the hot condensate exhausted from the cylinders, and using this 'flashed' steam to heat the low-temperature cylinders.

In the first stage, direct steam is blown in, without the use of an ejector, to the cylinders required to be worked at the highest temperature, so that the full temperature of the steam is available. In the second stage, exhaust steam from one group of the first stage, mixed with direct steam, is used for the cylinders which are heated with a lower temperature, but which still have to give a high evaporation of water. The steam exhausted from the first and second stages after separation from water has sufficient pressure to be used as the supply for heating the following cylinders with medium or low temperature. Its pressure is also sufficient to introduce exhaust steam of reduced pressure into these cylinders through an ejector. The steam exhausted from one group of cylinders is not put back into the same group of cylinders, but into one using a lower temperature. The third stage is provided with a small suction pump, which creates a vacuum sufficient to allow the use of evaporated steam from the hot condensate of the steam traps. Suction is provided by means of a pump-operated aspirator and assisted by a cooling coil. The coolest working cylinders are virtually under suction sufficient to enable the use of evaporated steam from the condensate, and utilise this steam as the



[Reiss Engineering Co.

FIG. 83.—THE V.J.B. STEAM CIRCULATION PLANT, SHOWING THE COMPLETE SYSTEM AS APPLIED TO DRYING CYLINDERS

source of heat. The cooling coil in the aspirator assists the suction pump by condensing all steam and so avoiding back pressure.

Thus the system may be said to work on the counter-current principle. The ingenious feature is that the cylinders are each arranged to work under a graded scale of temperature, and steam from one cylinder is re-used, but only in a position where the greatest benefit will result from its reduced temperature. The use of steam evaporated under suction for the heating of the low-temperatured cylinders is perhaps the most outstanding feature of the system. The whole of the piping is arranged so as to allow easy release of entrained air, and there are a sufficient number of cocks for this purpose.

Holmes and Kingcome Steaming System (Fig. 84).—This steaming system is based on the well-known principle of increasing the heat transference through any heating surface by increasing the velocity of steam applied to the opposite side of the surface; thus in the case of paper machines, the faster the steam is passed through the cylinders the more heat is passed through the cylinder walls, consequently giving increased drying power.

The method used to obtain maximum circulation coupled with economy of steam is shown in diagram.

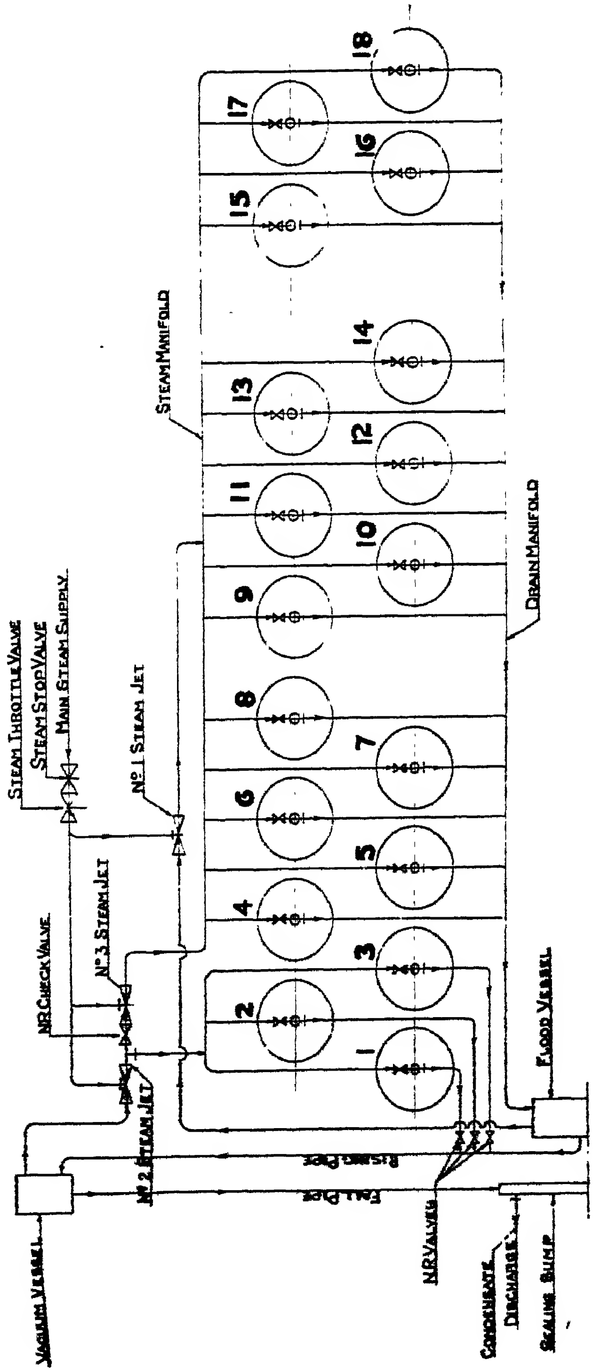
The steam is applied to three jets, the bulk passing through No. 1 jet which feeds all cylinders except the first three. As there are no steam traps or other restrictions in the piping, the steam passes straight through the cylinders and exhaust pipes to the flood vessel, where the condensate is separated from the steam, air and CO_2 escaping to atmosphere from a release valve. The separated steam is sucked off by No. 1 jet and blown through the cylinders again, and the condensate is sucked up into the vacuum vessel by No. 2 jet. As water under vacuum boils at a lower temperature, the condensate boils again in the vacuum vessel and the steam given off is used to feed the first three cylinders, the surplus being boosted up to main manifold pressure by No. 3 jet to be used again.

The resulting condensate left in the vacuum vessel falls down the fall-pipe, which acts as a barometric leg, and trickles out of the sealing sump. As this condensate has been under vacuum, its temperature is consequently very low.

Another valuable addition to this system is the use of an internal stationary steam jet inside the cylinder, which blows steam direct on to the cylinder wall at line pressure. By this method a still greater velocity as well as a drier cylinder is obtained.

All cylinders have to be very carefully balanced. A heavy side will cause a jerky motion, which makes the paper wrinkle or break. They are also graded in size, diminishing towards the dry end to allow for the decreasing shrinkage of the paper.

Besides the cylinders over which the web passes, each dry felt has one or more additional cylinders over which it runs on its return journey, in order



[*Holmes and Kingcome*

Fig. 84.—The Holmes and Kingcomb Steaming System

to be dried. This is commonly called the 'felt dryer'. The number of cylinders required on a machine depends on a great many things—the length and mesh of the wire, the number of suction boxes, the weight of the couch

and press rolls, the quality and substance of the paper, the speed, the steam pressure used for drying, etc. Obviously for a machine making a wide range of papers it is very difficult to suit the number of cylinders to all these conditions. For some papers eight would be sufficient; for others, five times that number would be wanted. From ten to twenty cylinders on an ordinary Fourdrinier is a fair average.

Felt Dryers.—It is at last being realised that the conditioning and proper drying of dry felts is a very important part of paper drying, and quite recently a very excellent type of felt dryer has been made available. While it has invariably been the case that certain cylinders have been added for the purpose of drying felts, something more was wanted, and the Happer dryer is an excellent solution of this difficulty of keeping dry felts in condition. It consists of a small drying cylinder rather like a suction roll and it is inserted between the sections of dryers in the same way as the felt-drying cylinder or in place of a carrying roll. As the felt passes over it, it is subjected to suction from a vacuum pump, and this draws the moisture away from the felt surface, and so dries the felt and leaves it in a condition to take any further moisture from the paper. This has the double advantage of conditioning the felt and the atmosphere around the dryers at the same time, for this reason: with the ordinary felt-drying cylinder the heat of the cylinder drove the moisture from the felt into the pockets, or under the hood of the dryers, still leaving this moisture to be dealt with by hot air and fans. In the Happer arrangement the water vapour is actually sucked away through the felt and exhausted to atmosphere outside the machine house, an advantage which will be readily appreciated.

Dry Felts.—Dry felts may be of cotton or wool. The latter are most efficient and last longer, but are more expensive in the first place. Cotton felts mark the paper and shed cotton fibres on it after a time, and for this reason may have to be discarded before they are quite worn out. Woollen felts shed a brown dust towards the end of their life, but by the time this takes place they are very much burnt and nearly useless. The cylinders should never be run when the wet end is shut for washing up or changing. After a few turns to get the felts thoroughly well dried the cylinders should be stopped, and the felts slackened off a little, to release the strain on their fabric caused by their shrinkage on drying. The felt-drying cylinders must have full steam on when the machine is running. This is much more important than is generally recognised. Owing to the blocking up of a steam-pipe leading to the drying cylinder, a woollen felt that would normally have run for six months became rotten and went to pieces in a fortnight. On many machines dry felts are guided by hand, but there is no reason why this should be so, as automatic guides are simple and easy to fit. The lines of a dry felt must be kept straight,

otherwise drying will be uneven, owing to the felt being tighter at one side than another. In many cases guide rolls will be found in the wrong positions. To check the felt, the roll has to be altered in such a way as to send the line off the straight. All fast-running machines now have automatic felt guides.

The guide roll should be on a stretch of felt where altering its parallel does not materially alter the tension of the felt. It is bad policy to run a felt too long. A felt may look to be capable of a few weeks' more work, but it may be, and usually is, worn thin in the centre, and this makes drying very difficult.

This will be reflected in unequal finish later on, especially on machine-finished papers, and cockles, etc., on thin papers. Much more steam is required to dry paper if the felts are well worn.

The satisfactory drying of paper on the Fourdrinier machine and the prevention of condensation in the machine house constitute two difficulties which until very recently have been unsurmounted by paper-makers and paper-mill engineers. The extra output required during recent years, in order to keep up with competition from new mills, has often been badly handicapped by lack of sufficient drying power at the machine.

For whereas it has often been found possible to speed up an old machine mechanically without detriment to the paper, it has usually been found that there were not sufficient drying cylinders to dry the paper at a great speed, and, what is more, no room to put in additional cylinders. In one mill at least this trouble was overcome by adding a third tier of cylinders above the existing two. To get over this drying problem the present tendency is to introduce warm air into the machine room and blow it into the 'dead pockets' among the drying cylinders.

Vapour absorption plants are in use in many mills and give very good results, both in increased output and also in the saving of dry felts. They have superseded the earlier method of introducing warm air through ducts under the roof, for while this plan certainly helped very greatly in reducing the condensation of water on the roof and girders, it could not be said to add much to the drying efficiency of the drying cylinders. The system of vapour absorption by hot air both increases the drying power of the machine and at the same time prevents condensation above the machine by absorbing the vapour as it leaves the paper, thus preventing it from ever reaching the roof in a saturated condition.

The vapour is chiefly released in the pockets between the drying cylinders, where there is very little natural movement of air, and fog or steam can nearly always be seen hanging about there. With the Sturtevant and similar systems warm air is introduced into the 'pockets' by means of specially designed perforated pipes. These pipes have perforations which ensure that the air

is discharged directly on to the felt, or paper, whilst at the same time surmounting the difficulty of projecting nozzles which interfere with the work of clearing broke and feeding through.

The air is drawn from outside by a centrifugal fan, and is blown through a steam heater. The apparatus may be placed in almost any position in the machine house or even outside it. The heater can be fed entirely by exhaust steam, or may be divided into sections, one using exhaust steam and the other live steam.

The warm air from the heater is distributed throughout the length of the dryer by galvanised sheet steel ducts, which in turn feed the various pipes distributed into the pockets, or above and below the felts of the machine. The drying capacity of the machine can be increased 15 to 25 per cent, with a corresponding increase in possible output. Fog in the machine room and drip from the roof are usually considerably reduced, and there is no need to emphasise the importance of this latter benefit, for it is bound to save many hundreds of pounds a year in breaks and broke, at least in mills where trouble is experienced from roof condensation, besides the great saving in roof maintenance costs.

The length of life of dry felts in one mill we know was increased as much as three times when this system was installed, and the output was at the same time increased by 15 per cent.

There is no doubt that it is a much cheaper and quicker way of adding to the drying power of a machine than by the usually very inconvenient method of installing extra dryers.

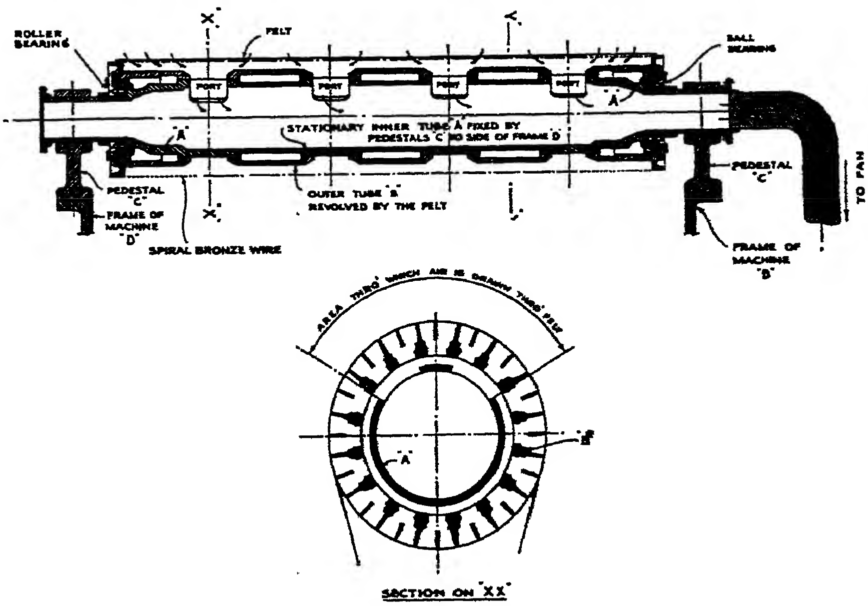
The 'Happer' Patent Felt Drying Roller (Fig. 85).—An important point to ensure even drying of the paper and freedom from cockles is the keeping of the dry felts evenly and properly dried.

Dry felts absorb a lot of moisture from the paper as it is driven out by the heated cylinders, and they ought to be able to pass it away to the atmosphere continually, in order that the wool may absorb further moisture on the next revolution of the felt.

Originally felts were dried by passing them over separate drying cylinders not in contact with the paper. A further improvement on this was the blowing of hot dry air on to the felt and into the pockets between the cylinders in order that this air might absorb moisture. This air was subsequently drawn away by fans. Both these methods have the defect that only the surfaces of the felts are dried, the moisture remaining in the vicinity of the paper-making machine, and some of it recondensing on to the felts. Also the hot and humid conditions in the machine house, brought about by this method of dealing with the moisture, make the working conditions unpleasant and cause troubles such

as condensation on any cold parts of the machine frame and roof and walls of the machine house. This causes damage to steel work, and falling drops of moisture, which are very troublesome when they fall on to the paper machine.

Several methods have been put forward to tackle this question of the conditioning of dry felts, but the one which seems to be the most successful and which is very satisfactory in use is that known as the 'Happer' patent felt drying roller. These rollers, which are illustrated in Fig. 85, can be put on in convenient places among the drying cylinders, and their construction is such that, as the felts pass over the roller, the heat and moisture-laden air are drawn right through the felt into the inside of the roller and conveyed by fan and



[*Messrs. Hall and Kay, and Bentley and Jackson*

Fig. 85.—The 'Happer' Patent Dry Felt Drying Cylinder
(The illustration shows a complete section of the roll)

delivery duct out of the machine house. In addition, the rollers are wound with a bronze wire in such a way that wandering of the felt is greatly reduced.

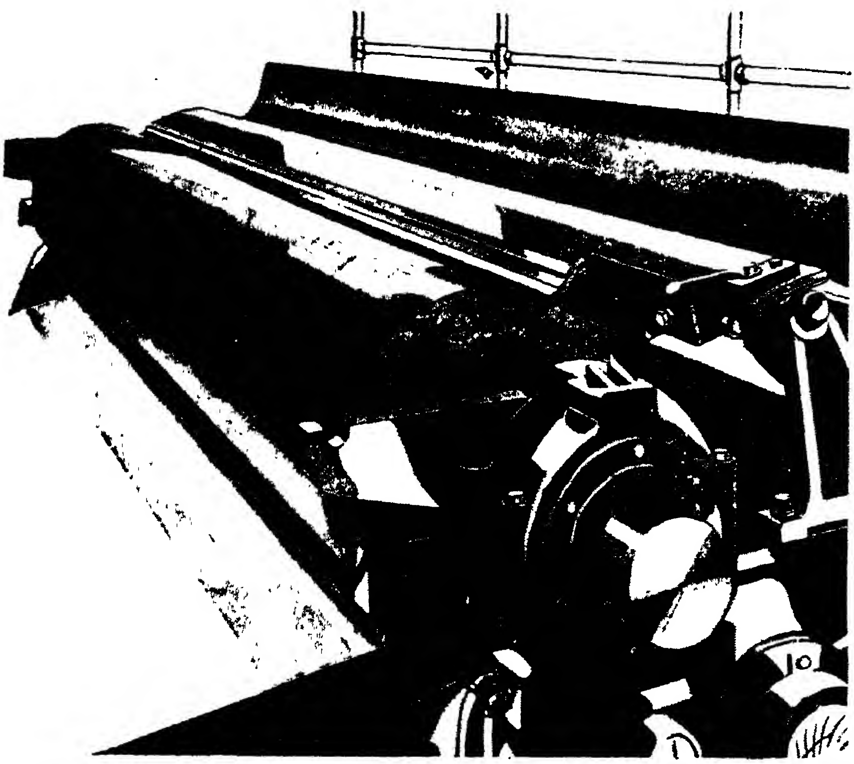
It will thus be seen that this method not only conditions the felt, but has the added advantage of removing some of the moisture-laden air from the room, or at least it does not allow this moisture-laden air to be blown into the room.

By placing a number of these rollers at suitable positions among the drying cylinders the felts are maintained at a much higher average standard of dryness than can possibly be attained by some heated cylinders, and there is not so much danger of the browning or burning of the felts. The felts are evenly dried across the full width of the web, and the moisture is drawn right through, thereby keeping the felt in much better condition, and more open and porous.

From our own experience we can say definitely that these 'Happer' rollers are by far the best method yet introduced for the satisfactory conditioning of dry felts, and for ensuring evenness of drying across the full width of the web.

The Heimbach system works on the opposite principle and blows dry air through the felt into the machine house. This air becomes saturated by taking up moisture from the felt, and has to be extracted from the room by means of fans.

Smoothing Rolls.—These are two steel rolls, steam-heated, and are inserted



[*Vickerys Ltd.*

FIG. 86.—VICKERY FLEXIBLE DOCTOR APPLIED TO A PRESS ROLL

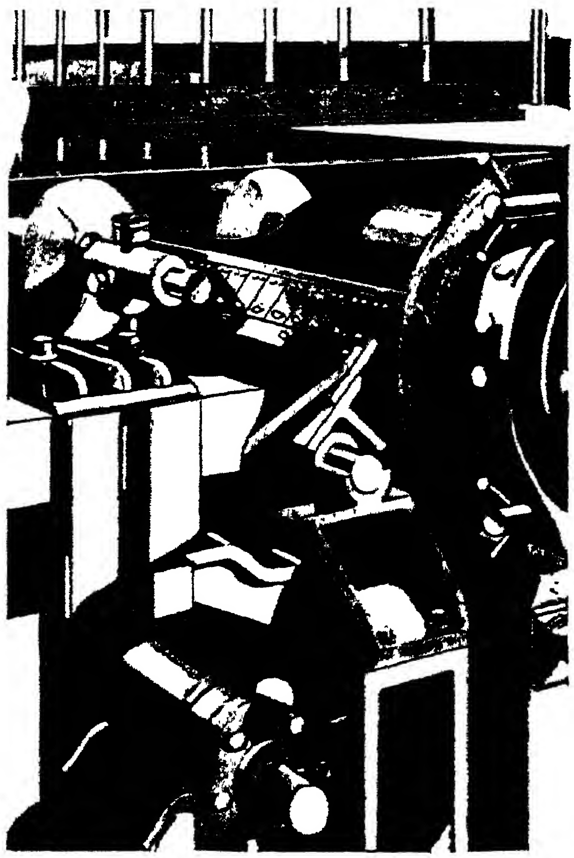
before the last section of drying cylinders. Their purpose is to smooth or flatten the web of paper while it is still in a slightly damp condition. They reduce bulk a good deal, but, if rightly used, are very effective in eliminating felt marks, and, by closing up the under side of the sheet, produce a very equal-sided paper. They should be run fairly hot, but not excessively so.

Good doctor blades are necessary for both rolls, as any particle of stuff or dirt may stick very firmly to their surfaces owing to the heat used.

The flexible doctor (Fig. 86) has revolutionised 'doctoring' of all rolls on the paper machine, and it is rapidly displacing the older forms of rigid iron

doctors in most positions. It consists of a row of springs fixed to a rigid holder, and these springs are slotted to take a flexible thin steel blade. It will be easily understood that this flexible doctor blade readily accommodates itself to any irregularities on the roll, and to variations in the position of the roll—*i.e.*, when paper is being led through at one end, and so tilting the roll out of parallel with the doctor support.

In order that the blade may take up these distorted positions, it is obvious that it must be capable of moving sideways, as the distance between the ends will be less in these positions. The blade, being only lightly held, can slide sideways to make up for these distortions.



[*Vickerys Ltd.*

FIG. 87.—VICKERY PATENT FLEXIBLE DOCTOR APPLIED TO A BREAST ROLL

Being thin and of light construction, the doctor rapidly responds to differences of temperature, such as the heat of calender rolls, M.G. cylinders and intermediate rolls. It keeps the surface clean and polished and in good condition.

The blades never need to be filed and fitted and they last fairly well, even on fast news machines.

The blade itself, when worn out, is very easily replaced, only a few minutes being required, in place of the hours often necessary with the older types of doctor, which had to be filed until they fitted approximately.

A new type of blade is being used with great success for keeping rolls clean. This is made of a bakelised cotton substance which takes on a very keen edge, and seems to be self-sharpening. It can be used on breast rolls, wire rolls, and press rolls, and fits more snugly to the roll than an iron doctor. It has many advantages over wood and iron, and is less likely to groove the surface with which it comes in contact.

Calender Rolls.—Most machines making E.S. papers have three sets of five rolls each. A very good machine finish may be got with these, but some

machines are fitted with as many as five sets, of which the first two sets may be of three rolls each. All rolls are cambered to take an increasing weight towards the reel end, and are fitted for steam heating, and have doctors and guards before each ingoing nip. The bottom roll of each set is greatest in diameter and is driven. The other rolls are driven by the friction between their surfaces and the paper.

After passing through the calender rolls the paper will have received its surface finish, and as a result of the heat and friction of the rolls, it is always charged with static electricity. Sometimes this charge is very high, especially so when the rolls are very hot and the paper has been allowed to get a little too dry. Then trouble is experienced with the laying of the sheets when the paper is being cut. They are attracted to parts of the cutter and also to each other, which interferes with the 'picking' or overhauling later on. To cause this electricity to be discharged the paper is led from the calenders over a water-cooled cylinder or cylinders. Where these are not fitted, copper wires are stretched across the machine, close to the surface of the web, and earthed to a water pipe or to the frame. Conditioned paper is, of course, freed from all static.

The web is wound round on a wooden or iron bobbin by means of a friction winder. A square spindle or bar is put through the bobbin and the latter is secured in its place by 'keepers'. At one end of the spindle is a small cogged wheel. The friction winder is composed of a shaft which carries a cogged wheel to engage in that on the bobbin spindle. On the shaft are two steel discs, one of which is fixed; the other is free to move sideways. Between these discs runs a pulley which comprises two polished sides. Leather discs are interposed between the fixed discs and the running pulley discs.

The pressure between these discs is adjusted by a screw handle and the friction gives the necessary tension to the spindle and web of paper. Drum winders are also used.

The Machine Drive.—The 'drive' is the term used to express the means by which the various sections of the machine are connected to the source of power, and includes the latter. Formerly one steam engine was used to drive the various pumps, etc., of the wet end and also the machine itself. In still earlier times it was not unusual to find a water wheel doing the work. The means of power transmission was by belts and shafting geared to the engine with spur wheels; as the wet end machinery cannot be varied very much in speed, the range of speed for the machine was very limited.

To overcome this difficulty, intricate arrangements of 'speed wheels' were used when very heavy or light substances were being made. This entailed shutting down and lifting on and off heavy gear wheels, or putting

intermediate wheels and shafts into action. Later on two steam engines were used, of which one drove the wet end at a constant speed and the other the machine itself from the wire onwards. This was a great improvement, but the steam engines were of too heavy a type, with a limited range of speed, and 'speed wheels' were still necessary. Their heavy flywheels, parts and long stroke prohibited a high speed, so there was only a limited range of speed at which they could be used with any efficiency.

The reciprocating action of these heavy engines caused the belts to swing, and the sections of the machine were very jerky and unsteady, and this was the source of endless broke.

Many had no variable governor drive, and the speed was altered by hanging more or less weight on the governor lever. As the necessity for higher speeds arose, and to dispense with the inconvenience and loss of shutting down to change speed wheels, the smaller type of high-speed light engines was developed, and proved a great advance in steadiness and efficiency.

In the old type of belt drive the usual arrangement comprised a series of gear wheels of various sizes, which had to be changed to suit the speed required. The first press rolls were driven direct through a clutch on the main shaft. On this shaft were three pulleys, from which one belt drove the wire shaft, one the shaft for the main stack of drying cylinders, and the third the shaft for the second press. On the cylinder shaft were the pulleys of the smoothing rolls, the second stack of drying cylinders and the calender rolls. From one or other of the calender roll shafts, belts extended to the cooling rolls, winder, etc.

The sections of the machine were put in gear by means of toothed clutches, which started them up with a sudden jerk, imposing a great strain on the belts, and specially on the teeth of the cylinder gearing. In fact, the engine had to be slowed down to put the cylinders into motion, and unless this was done the wheels were sure to be stripped of teeth.

The tension of the 'draws' was regulated by sticking on the pulleys, to increase their diameter, pieces of 'packing', strips of old coucher covers, old dry felts, etc., by means of resin boiled with oil and pitch. This had to be done when the machine was running, and was a troublesome, difficult and dangerous operation. The tendency of the pull of the belts was to drag the 'packing' into lumps, and in hot weather the resin refused to remain sticky enough, so that pieces fell off and had to be continually replaced. When a piece of packing could not be got off a pulley, a piece had to be stuck on the other to get the draw correct, and the belts frequently stretched and broke under the strain. The provisions of the 1937 Factory Act preclude the use of this type of drive.

The introduction of the high-speed engine and variable speed electric motors made it possible to arrange a drive which has none of these faults.

Instead of heavy belts in series, the engine drives a shaft, usually overhead, from pulleys on which each section is separately driven through bevel wheels, the smaller of which is of hide, giving a smooth and noiseless motion. Light belting (4 to 6 inches) is used, and cone pulleys supersede the packing method.

In another type—'White's drive'—the power is transmitted by a system of ropes instead of an overhead shaft, and cone pulleys with light belts are used to vary the speeds of the sections. No clutches are used, the driven cone pulley being raised by a lever so that the belt is put out of action, and has no wear and tear unless the section is being run. When starting up, the pulley is lowered into the loop of the belt and the section starts gradually as the belt is tightened up. This has shown itself to be a very efficient, smooth and steady drive.

The Marshall Drive.—The Marshall drive transmits power to the various driving sections of the machine from a line shaft running parallel to the length of the machine. Each unit allows a certain amount of speed adjustment, and turns the drive through a right angle to couple to a driving shaft which lies in a cross-machine direction.

In every stage of its development the unit has consisted of a shaft carried by bearings and stands from the machine house floor, and driven from the line shaft by clutch-operated cone pulleys, the latter being provided with belt-regulating gear to give speed adjustment. The shaft of each unit has fitted at one end a bevel pinion which gears with a bevel wheel on the section driving shaft.

The advances made in the design of the Marshall drive since its first inception consist mainly of improvements to the gear wheels, and the replacement of ordinary bearings by anti-friction bearings of the roller or ball type.

The first arrangement of gear wheels would almost certainly have an iron pinion with cast teeth, working in conjunction with a mortise wheel having teeth of hornbeam or birchwood fitted into a cast-iron rim. Later, both wheel and pinion would have cast teeth, and then in turn these would be replaced by gears with machine-moulded cast-iron teeth, and eventually by machine-cut teeth. Up to this period the gear wheels had worked without any serious attempt being made to enclose them, and lubrication consisted of an application by hand of heavy oil or grease at frequent intervals. With the advent of bevel gears made from high-tensile steel and having spiral teeth, the Marshall drive entered the field of precision engineering. Gears that were now only about half the diameter of the originals, but transmitting the same power, required protection both from dust and from the effects of faulty lubrication. It thus became necessary to enclose the gears in cases that were both dust- and oil-tight.

These modern units with gears running in oil, on shafts equipped throughout with roller bearings, occupy a minimum amount of space and are practically noiseless in operation.

Most machinery manufacturers make a range of units of various power capacities, each with variations in gear ratio. Their design allows ample adjustment to be made to take up wear in the taper roller bearings, and also has ball bearings fitted for the cone pulley to revolve upon when the unit is not transmitting power.

[*Harland Engineering Co. Ltd.*

FIG. 88.—HARLAND DRIVE ON 200 INCH BOARD MACHINE

Multi-Motor Drive.—The Harland drive (Fig. 88) is of the sectionalised type with a motor on each section, the motors being coupled through double helical gears to the paper machine driving-in shafts. For the purpose of maintaining relative desired speeds on the motors, a master reference is provided. In the original system a light shaft was run along the full length of the machine, this shaft being driven from the dryer section or by a separate master motor. In the up-to-date version an 'electrical master shaft' is employed, giving greater flexibility of layout and control.

Each section is provided with a differential regulator, one shaft of the differential gears being coupled to a small synchronous motor running in synchronism with the master alternator. The second shaft of the differential

[*Harland Engineering Co. Ltd.*

FIG. 89.—THE HARLAND INTERSECTION SPEED REGULATOR UNIT

gears is driven by means of a belt and cone pulleys from the motor to be controlled, while the third member of the differential actuates the special shunt regulator in the motor field.

The speed of the master alternator determines the speed of the paper machine. It is direct coupled to a small master motor.

As is well known, the speed of the third member of any differential gear is the resultant of the speeds of the other two shafts. When the first and second

[*Harland Engineering Co. Ltd.*

FIG. 90.—HARLAND DRIVING UNIT

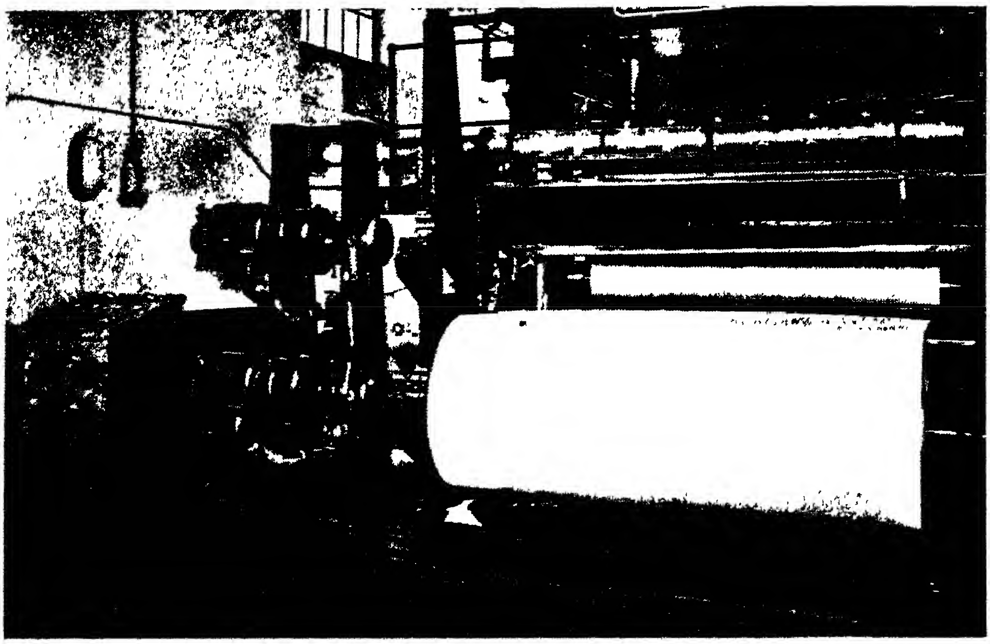
shafts are running at the same speed in opposite rotation, the third member, which is connected to the regulator, will remain stationary. Immediately there is any difference in the speeds of the first and second shafts, the regulator will move in the required direction to correct the motor speed. If the load changes—say, increases—the motor will tend to run slower, and as soon as this happens the first and second shafts will not be in equilibrium, and the third member will move the regulator and weaken the field until the two shafts are running at the same speed again. If load is thrown off, the reverse action takes place.

The system is absolutely positive, the three members of the differential gear being mechanically locked together, and the smallest change in speed

between the first and second shafts is at once shown by movement of the regulator.

Correction of an error in section motor speed is made very quickly, the response of individual regulators being designed to take into account the differing characteristics of inertia and frictional damping to give maximum drive sensitivity without hunting, the accuracy of control being such as to avoid strain on the web of the paper.

A view of the differential regulator unit and the small synchronous motor



[*Siemens Schuckert*

FIG. 91.—VARIABLE SPEED ELECTRIC REEL-UP, ENABLING HARD OR SOFT ROLLS TO BE MADE

is shown in Fig. 89. The differential gears are housed inside the regulator case, while the cone pulley shaft projects at the back of the case.

In Fig. 90 is shown a typical section motor with interlock equipment and cone pulley transmission to enable the draw of the section to be varied. Suppose the belt is in position as shown in the illustration and it is required to alter the draw by decreasing the speed of the motor, the belt must be moved by means of the belt-shifter towards the large diameter of cone on the motor shaft; this increases the speed of the second shaft of the differential gear and causes the regulator to move and reduce the speed of the motor until the second shaft coincides in speed with the first shaft. The regulator arm has now assumed a new position on the face-plate, giving the required field strength for the new speed.

The draw is increased or decreased without breaking the paper or interfering with the running of the machine.

The drive takes up very little space, and may conveniently be housed either alongside the paper machine or outside the machine room in an annexe, with the driving-in shafts passing through the wall or partition, as shown in Fig. 88. It is very compact and accessible, and does away with all troubles from belts, ropes and clutches.

The drive is very efficient and provides great flexibility of layout both from the point of view of mechanical arrangement and control. In particular, the drive to each section of the paper machine can be designed to suit the inertia and frictional loading characteristics to ensure equal accelerative response on all sections to any common change in speed, thus relieving the paper of tendency to tighten or slacken between sections under such conditions. The speed of the whole paper machine can be maintained so constant as to limit the variation to a fraction of 1 per cent, a factor of considerable importance for high-speed paper machines. All control can readily be arranged at the front of the machine in the most desirable positions for machine speed as a whole, section motor inching, crawling, starting and stopping and draw adjustment with local indication of speed, power requirements and draw settings. Individual sections of the machine can be shut down, inched or crawled without affecting the correct interlocked running of the remainder. Heavy sections can be electrically braked for quick stopping, thus minimising delays and tending for safety in the event of accident.

The ease of control, speed constancy and reliability of this form of drive combine to give maximum output of highest grade product, and it is not surprising to find its application being extended to all classes of paper-making machine, both large and small.

The British Thomson-Houston Company also make a sectional electric drive which is in use on paper machines, and a recent improvement is the separate driving of each individual cylinder which has been developed by Siemens, who were licensees for the Harland system. For certain papers this system possesses definite advantages.

CHAPTER XIV

PAPER-MAKING ON THE MACHINE—WATER-MARKING

Notes on Machine—General.—As paper-making on the machine varies so very much with the qualities, substances, etc., of paper, it would be futile to attempt to lay down hard-and-fast rules as to how the various parts of the machine should be used. The machineman has to exercise his judgment, and must have at his command numberless 'dodges', if we may be allowed to call them so, for getting the results he wants.

As far as the strainers there is little that may be called 'paper-making'. It is when we get the stuff to the wire that the art and skill of paper-making commence. The slices are the first consideration, and these have more to do with the look and strength of the sheet than may be supposed. On some machines there is a lifting gear to raise or lower the breast roll end of the wire frame. A low level will cause a deep 'dam' to form behind the slices, and a deep pond will remain after them. Under the influence of the shake this might be expected to close up the texture of the sheet, but it is not always so. The rising slope of the wire will result in the stuff and water rolling over and turning on itself, and a cloudy, though well water-marked, paper will be made. This is what is generally wanted for laid ledger papers of a certain class.

By raising the breast end a little the stuff will flow out from the slices more freely, and though not being so long under the influence of the shake, will produce a closer-looking sheet.

The same result can be obtained by increasing the speed of the machine, and taking the stuff away from the slices before it can get time to roll back. Thus if the breast end is fixed at one level, the speed of the machine may be used to do the same work as a lifting gear. Again, if we have a deep dam behind the slices—*i.e.*, the slices close down on the wire—the stuff will shoot out and forward, and go well up the wire, and get very little good from the shake. Also, the fibres will be turned round and set on edge by being forced through a very fine opening. This makes a raw and badly water-marked sheet.

By raising the slices the fibres will flow gently on to the wire, and the shake will get hold of them at once where the longest throw occurs. Then the fibres will be well felted and closed up, and the sheet will be found to be stronger and closer in texture and have a clearer water-mark.

Therefore, though a lifting gear at the breast end gives a little more chance of varying the conditions, it is by no means a necessity for an ordinary machine. By using the slices intelligently and getting the proportion of stuff and water correct, its absence will not necessarily be a disadvantage.

The behaviour of the stuff and water on the wire is a very interesting study. It will be found that in every case there are long fibres and fibrillæ, some of the latter so fine as to be nearly powdered. On emerging from under the slices, if the water is nicely proportioned, the long fibres fall to the under side of the sheet, and the fibrillæ remain for a time in suspension with the water. The action of the shake, contrary to what one might expect, keeps these finefibrillæ suspended for a time, until they are sifted into the spaces between the longer fibres, and by the gradual drawing out of the water by the tube rolls they remain there permanently. As the stuff approaches the first suction box, the action gradually ceases, so that the suction sets the sheet without altering the disposition of the fibres. It seems to be a fairly general belief that the shake turns the fibres from their 'end-on' flow from the apron. But a simple experiment will show that this is a fallacy. Take a few matches and float them in a rectangular tray. Give the tray a sideways shake and the matches will arrange themselves broadside on to the direction of the shake. Close observation will show a similar action on the wire when the stuff is beaten rather raw and long. It must be remembered that the shake does not make a *flow*, but, what is quite a different thing altogether, a *wave*.

Actually, with a well-fibrillated stock, the longer (or any) fibres are not moved much, if at all, from their endways flow. Moreover, the end-on flow of the fibres from the apron is not so pronounced as is generally supposed. The passage under the slices tends to turn round fibres that are pointed endways, especially the longer and bulkier ones. These, being entangled with fibrillæ, will naturally remain very much in the position in which they emerge. If they do alter their position, it will be towards placing themselves end on, because the shake is forcing them to this position.

An examination of paper made with and without shake will show this to be correct. The increase in strength given by the shake is due to the fibrillæ being spread and sifted into what would otherwise be bare spaces, or air spaces, and making a uniform in place of a 'patchy' paper. If there is too little water with the fibres, the fibrillæ will not be so sifted, because their carrying medium is absent. If too much water, they will not have settled before reaching the suction box, but will still be in a suspended state. Then too much suction will have to be used, and the whole fabric of the sheet will be disturbed.

A long wire is not always an advantage in making strong papers. The

extra water which is used and the extra time the stuff is under the influence of the shake give the shake more opportunity of bringing the fibres into an end-on position. Ledger and other strong papers made on a 50-feet wire have a more pronounced difference in breaking strain across and along the sheet than those made on a 40-feet wire, and it also is more difficult to give the sheet the characteristic look of strength combined with clear water-mark which is a feature of good ledger papers. If it is desired to give to a paper made from rather poor stock the *appearance* of strength, a deep dam behind the slices will cause the stuff to rush well up the wire and get very little result from the shake. It will then *look* strong because the dandy roll has no nice level surface to impress, and the fibres will be arranged in all directions, but it will have less strength than if made a closer-looking paper.

In trying to make a close, well water-marked sheet from stuff that is not well fibrillated, extra water and shake will be effective only up to a certain point. That point has been reached when the fibres are not settled into a compact body before reaching the suction box. Less shake may be tried, or if shake is known to be not above normal, less water is wanted.

Too much water and too little shake, or either alone, are shown by the formation of water drills. These are thin streaks made by the water running in channels along the wire and refusing to amalgamate with the stuff. More often too much water is the cause. But a wire that is dirty in streaks, or badly beaten stuff, will also give the same trouble.

Stuff that is beaten very fine—*i.e.*, very much *cut* by the beaters—is easily water-marked, and looks 'wet' on the wire, but is shown to be free when passing over the suction boxes. This style of beating and paper-making makes a very nice close sheet and a clear, bright water-mark, but the strength is very poor for the quality of the stock used. Water drills are very often prominent in stuff of this description.

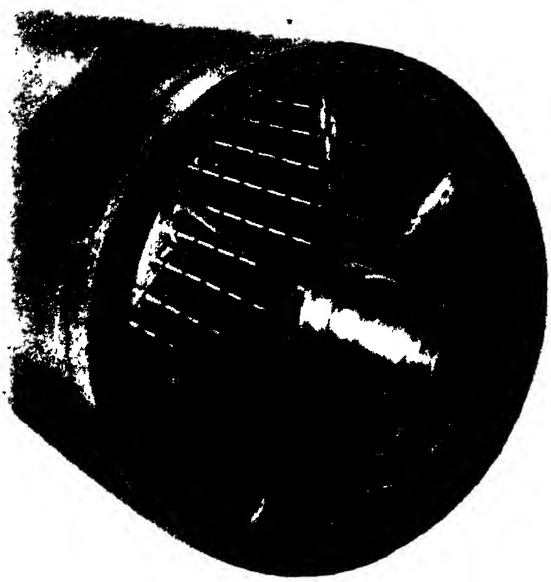
It may be mentioned in passing that fresh water is more productive of water drills than the softened back water of the machine; also, if fresh water has to be used to supplement the back water of the machine, it is much more difficult to make a close sheet.

In making an engine-sized paper the slices have to be closer to the wire than would be otherwise desirable, in order to keep back the froth which forms on the breast of the machine. Very often with strong stuff, and with papers containing a large proportion of wood fibres that have been kept a good length in the beater, numberless clear specks and spots appear in the paper. These are caused by the chemical action of resin, alumina, hard water, etc., forming carbonic acid gas (CO_2). This formation of gas takes place on the wire itself as well as before it. The little bubble of gas keeps the fibres from

settling on the wire, and when it bursts, it is usually too far advanced towards the suction box for the hole to be closed up again. The remedy is to use as much water with the stuff as is possible, to fill the space again that has been made by the bursting of the bubble. Beating the stuff finer, or running at a slower speed, will also effect an improvement. Entrained air and other gases, sometimes caused by the chlor-lignins, also cause these froth spots.

Froth is often a great nuisance on the machine, and sprays should be provided to keep it down as much as possible.

A little extra alum will sometimes be of great assistance, or a little paraffin



[*Green, Son and Waite*

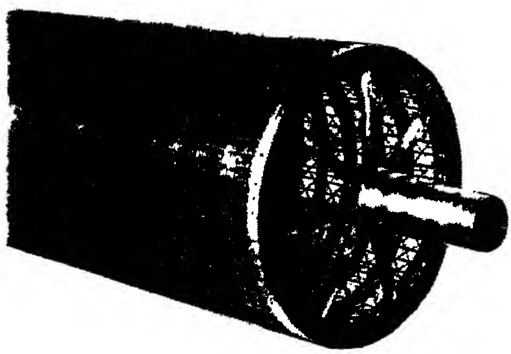
FIG. 92.—WOVE ROLL

run into the stuff from a tin above the chutes by means of a woollen thread, where this is otherwise permissible.

Steam Heating of Stock.—The effect of raising the temperature of the stuff and water on the machine is to make it work more 'free'. Advantage is taken of this fact when making heavy substances or running highly fibrillated stock. By raising the temperature to about 90° to 95° F. an extraordinary change in the working of the stuff on the wire can be observed. The fibres swell up and become more rigid, the meshes of the wire open a little owing to the expansion of the metal, and, chiefly important, the tenuity of the water is increased and its surface tension lessened. The effect of these things is that the work of the suction boxes, and consequently the strain on the wire, is made much less. More water and shake can then be used and a closer and more

clearly water-marked paper can be made. The best situation for the steam-pipe is in the top-level water box. A stronger paper may be made from heated stuff than from the same stuff run cold.

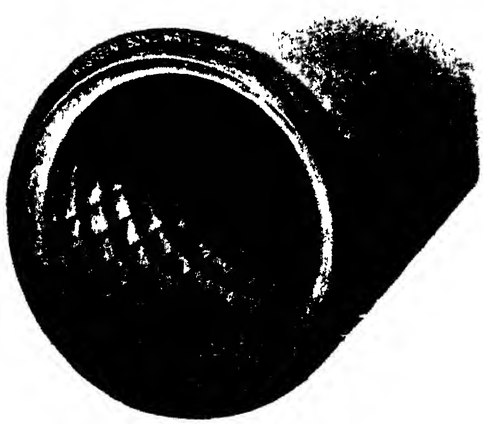
The Dandy Roll and its Use.—The body of a dandy roll is a brass tube on



[*Green, Son and Waite*

FIG. 93.—LAID ROLL, ORDINARY JOURNAL TYPE

which are fixed a number of brass discs and a framework of cross-wires. A cylinder of wire cloth similar in mesh to a machine wire is pulled over the body and fixed at the ends. This is called a 'wove' roll (Fig. 92). The centre tube is extended as spindles, which run in the bushes of adjustable



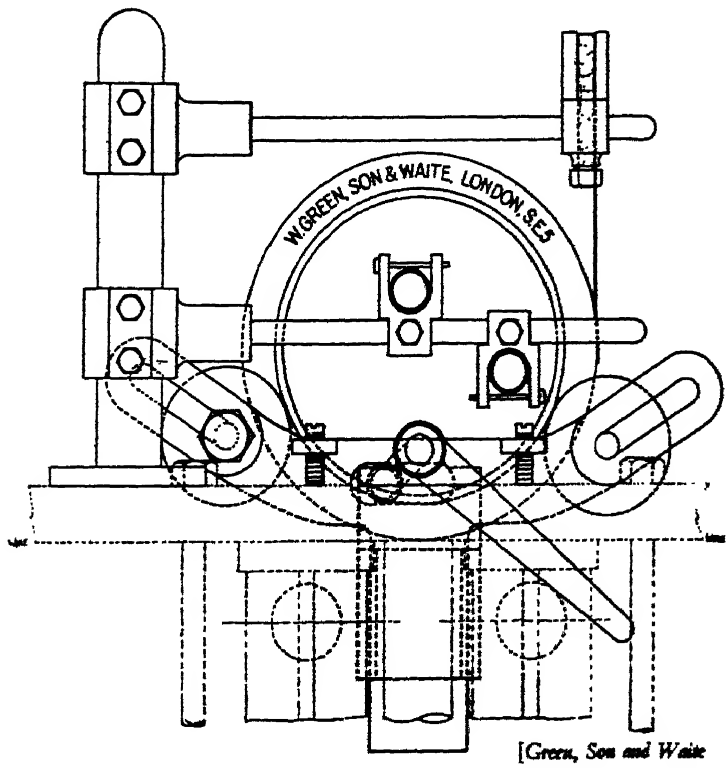
[*Green, Son and Waite*

FIG. 94.—WOVE DANDY ROLL, HOLLOW TYPE

brackets fixed at each side of the machine, between the first and second suction boxes or in a position found most suitable. A 'laid' roll (Fig. 93), instead of having a woven cover, has one made from parallel wires. These are kept apart and in position by twisted wires round the circumference, from $\frac{3}{4}$ to

$1\frac{1}{2}$ inches apart. These are called the 'chain' wires. Letters and devices of wire may be sewn or soldered on the surface of the roll.

Hollow Dandies.—Nowadays increasing use is being made of hollow-type dandies having no spindles or journals (Fig. 94). These are very rigidly constructed and have many advantages over the old type. In the first place they run on a rim supported by rollers on ball bearings, and have a very fine adjustment (Fig. 95). The bracket which is illustrated also has a quick lift lever, enabling the dandy to be lifted clear of the wire instantaneously. The fact that the dandy



[Green, Son and Waite

FIG. 95.—DANDY STAND, BEARINGS AND ADJUSTING MECHANISM FOR HOLLOW DANDIES

is hollow enables stationary steam- and water-pipes to remain inside the dandy and to be used continuously or intermittently for cleaning it from the inside. The advantage of this will be obvious. It is also possible to fit a stationary tray inside to catch water and pieces of stuff, and run them clear of the dandy.

The introduction of these hollow dandies has enabled much greater speeds to be attained without deterioration in the quality of the paper, and it is possible to run these dandies for 6 to 8 weeks continuously without having to remove them from the machine for cleaning.

The function of the dandy roll is primarily to assist in closing up the sheet by pressure on the fibres while in a wet state. For this reason a roll as heavy

and large as can be run on the substance should be employed. Where letters or devices are on the roll, and require to be spaced for registering accurately a certain size of sheet, the size of the roll has to be accommodated to the size of the sheet. The letters or devices, being raised above the surface of the roll cover, impress themselves on the stuff on the wire, and by making thin places where they touch, cause the design to be transparent when looking through the sheet.

This is called the 'water-mark'. The clearness of the water-mark depends upon a great variety of circumstances, among which the chief are the amount of water left in the paper after passing the suction box or boxes in front of the dandy; the quality of the beating; the quality of the fibres and their length; the weight and diameter of the roll; the thickness of the wire forming the letters or designs; the speed of the machine; the substance of the paper, and the skill used in closing up the paper on the wire. Subsequent operations on the machine, and the finish, also affect the water-mark. The couch rolls and presses all contribute a little towards taking away the clearness, and so does a very high finish, which may go so far as nearly to obliterate it altogether.

The proper amount of water to leave in the paper to get a good impression from the roll is altogether a matter of experiment. The suction is altered until the desired result is obtained. If too much water is left, the paper is crushed by the dandy roll; if too little, the roll makes a faint water-mark. Very fine stuff gives the best results in wove papers. The wires sink into the body of the paper without encountering any long or hard fibres. Well-fibrillated stock is required for the good water-marking of thin substances. A good laid mark requires longer stuff.

The fine fibrillæ on the surface take the impression well and long fibres on the under side help to sustain the weight of the roll and prevent 'pick up'. Soft, fine fibres such as esparto are easily water-marked. The wires of a design on a small diameter roll stand at a more obtuse angle from the circumference than they do on one of greater size. This makes them have a 'digging-up' action, which is very apt to cause 'pick up'. The figures on a large roll fall on the wire with more of an impressing motion, and are also supported by a greater plain area, which helps to press the water through the wire and prevents it returning to the impression and filling it up again.

Trouble is sometimes experienced from air bells with a wove dandy. A stream of air or steam, impinging on the roll as it rises from the sheet, stops the trouble, but if froth bells are coming along the wire their source must be found and stopped; usually more water will stop them. A laid roll with the laid lines arranged spirally round the circumference is used occasionally for cheap papers to attain a higher speed, but it makes but a poor water-mark.

When using a roll with letters or designs on a thin paper it will be found that the raised letters, etc., pick up fibres or bits of pulp, the size of which increases with each revolution, until they fall or are brushed off by the machine-man. These are termed 'dandy picks' or 'picks' and are responsible for a great percentage of broke in thin papers. A small diameter roll, or one with heavy designs, gives most trouble. The remedy is to raise the roll carefully, so as to take as much weight off the stuff as possible without losing the clearness of the water-mark, or to reduce the speed of the machine, or to increase the length of the fibres, by altering the beating.

Therefore the character of the water-mark and the suitability of the roll have to be considered when trying to increase speed on a thin paper. An increase of speed is of no value if the proportion of broke from this cause is also increased.

A strip of old wet felt, called the 'wiper', is suspended by a rod over the dandy roll, and may be let down on it when running at a low speed. It is an excellent device for keeping the roll clean and free from 'picks', if it can be used. Wove rolls are liable to fill up with froth, when they have to be taken off the machine and washed out. Fine sprays of cold water are sometimes used on the roll to prevent the froth forming. A rubber roller running on top of the dandy will be found of great use in collecting the bits of stuff picked up by the dandy. This roller throws them on to a cloth fixed in front of the dandy.

Dandy rolls with designs that must register correctly have to be set in correct parallel across the machine to bring the designs square with the cut sheet. The draws or tensions between sections of the machine are used to bring the water-mark correct with the cutting length or 'chop'. Often a roll will be found to be short in the draw, and after all the sections have been pulled tight the draw is still too short. A few turns of tape, or one turn of thin old wet felt round the ends of the dandy roll outside the deckle edge of the paper, will lengthen the distance between the designs, and it is more prudent to do this than pull up the sections too hard. If the wiper can be used, it will give a fraction of an inch more length by slightly dragging the roll. The register of the water-marks across the roll is more difficult to alter. On narrow deckles (up to 60 inches) they are seldom far out, but on wider sheets, such as four or five sheets of 16½ inches, the beating and quality of the fibres may alter the shrinkage by as much as 2 inches. The beating of the stuff must then be altered to bring the width into register with the roll. If the draws can be altered the width may be controlled a little, so that by putting a turn or two of tape on the roll the length may be brought out and the draws put back, which will give more space between names across the roll.

When ordering a new roll, the makers should be made aware of the quality for which it is to be used, when they can produce a roll with the water-mark spaced to come very correct.

Extra weight on the couch and press rolls will prevent shrinkage on the drying cylinders to some extent; so also will tightening up the dry felts, but in these cases the shrinkage is apt to take place later—*i.e.*, on the dryer after tub-sizing.

A laid dandy roll is more tricky to deal with than a wove. It is customary to have a small tube roll or a soft brush set exactly under the roll. This allows a little more water to be used after the suction box. The tube roll or brush takes away the extra water that is pressed through the wire by the weight of the dandy roll. But if too much water passes under the roll, it will 'lift' sections of the sheet partly off the wire.

These sections may be even lifted off the wire and stick to the roll for a few turns, when they come off and spoil the wire by passing through the couch rolls. If a good water-mark cannot be got without this happening, the make of the paper on the wire must be attended to. More shake and, if necessary, more water are required, so that more suction is used on the first suction box. This will ensure that the sheet is pulled down on the wire with more force than the weight of the dandy roll can exert to lift it up again.

A little manipulation of the tube roll or brush may be all that is necessary, but care must be taken not to raise the roll or brush so high that the wire is lifted off the suction boxes, or that the paper is made to look streaky. All dandy rolls should be allowed ⅛-inch play between the brackets, so as to allow for the slight movement of the shake, and to prevent them being dragged.

Dandy rolls being very delicate and expensive, too much care cannot be expended on their use and storage. They should be carefully washed out by means of a good jet of water when they are taken off the machine. If they are left standing for some time, while the machineman does something else, the frothy matters in the meshes will quickly dry up, and be very difficult to get rid of. Indeed, it is sometimes impossible to clean them without using strong acid, which is the worst possible enemy of the dandy roll.

A machineman who neglects to wash out and thoroughly clean a dandy roll immediately on taking it off a machine does a grave injustice to his employer and to his shift mates, who will perhaps be compelled to take drastic means of cleaning it before it can be used again. In any case, every machineman should carefully examine the condition of a dandy roll before he puts it over the wire, and report to his foreman any damage it may have received.

When the web has passed under the dandy roll the paper is made. Subsequent operations are simply water extraction, with the minimum of damage

to the bulk and water-mark and the elimination of felt and wire marks. Finish on the machine is a question of moisture, pressure and number of rolls used, and practical experience and experiment on the part of the machineman. Moisture content is controlled by the drying operation, and this again by the steam heat admitted to the drying cylinders. Several systems may be used by the dryer-man. A certain pressure may be admitted to several or all the cylinders and controlled by the main valve; or he may use the cylinders separately, admitting more or less pressure, according to the feel of the paper, without altering the main valve. The third and best way is to keep the pressure constant by using the main valve and to make finer adjustments separately on each cylinder.

The heat of the cylinders should be so graded that the paper gets no sudden heat, but is gradually raised in temperature as it travels towards the dry end.

It is very difficult to get and keep a regular finish on a paper-making machine. There must be a certain quantity of moisture left in the paper before it enters the calenders, and the condition must be the same all across the sheet. Any unequal pressure of the couch and press rolls, worn and damaged wet or dry felts, dirty or corroded places on the drying cylinders, unequal spread of the stuff on the wire or ridges in the latter will affect the moisture content of the paper and show up in the finish.

A change in the beating from wet to free, or *vice versa*, however slight, changes the conditions of the pressing and drying and upsets the finish. Constant attention and good clothing are necessary if the finish is to be kept accurate and constant to the sample.

Great care is required where using steam-heated rolls, as heat affects the camber, sometimes expanding the ends of the rolls more than the centres. It is best to heat the rolls thoroughly before starting the machine.

When the paper is put through, the result will enable the machineman to alter the heat, or put on more or less pressure to get a level finish. If the rolls are not heated in time there will be the greatest difficulty in heating them afterwards, owing to the cooling effect of the moist paper. As calender rolls are cambered to a certain pressure, any pressure over or under that point will cause uneven finish across the sheet. If the finish is not correct with the pressure intended for the rolls, the spread of the stuff on the wire must be slightly changed to suit the pressure required. Thus if an unequal spread gives a finish too high in the centre, by putting down the slice in the centre of the wire the paper will be slightly less in substance and will come along the machine dryer and take less finish. Too much pressure on the calender rolls, even when well cambered, gives high finish at the sides and low finish in the centre, because the rolls are sprung on the centre. This seems incredible with steel rolls of the usual diameter, but can be easily proved to be correct by experiment.

When an equal finish across the web cannot be obtained, the spread of the stock on the wire should be looked to. Too much pressure on the coucher and press rolls will make the edges of the web too dry, because these rolls also are cambered to a certain pressure and spring in the centre.

A badly worn felt which is most worn in the centre gives a high finish in the centre and low finish at the edges, owing to the edges pressing the paper against the cylinders harder on the edges than in the centre, this giving an unequal moisture content. Constant attention is required to keep the finish correct; when the exact finish is obtained the attendant should note the position of the carrying roll over which the web passes after leaving the cylinders. The spring will be found to tighten up when the paper is too dry, and to slacken off when it is too moist.

The average position should be noted, and if necessary marked, and the least change in moisture content will be quickly apparent. Another good guide is the amount of steam coming from the last dry felt as it leaves the paper. When altering the speed of the machine or the substance of the paper, the man in charge should always tell his assistant so that he is not taken unawares, but can shut off or put on steam beforehand.

Water-Marking.—The water-marking of paper is carried out in two distinct ways, depending on whether the paper is hand-made or made on a Fourdrinier machine.

In the case of hand-made paper, the design is formed on the wire cloth of the mould by sewing or soldering designs or letters in wire upon it. When the mould is immersed in the stuff, the wire designs or letters cause a thin place in the stuff, and this appears as a transparent place in the finished sheet.

A variation of this effect may be achieved by pressing or counter-sinking a design into the wire cloth, and in this case a thick place is made in the stuff—*i.e.*, more stuff is deposited there—so that a dark or thick mark appears in the finished sheet. A combination of thick and thin places may be produced on the same sheet and very fine effects may thus be obtained.

The water-marking on some currency and bank-note papers made by hand, and also on the machine, is very beautiful, and requires a high degree of skill on the part of the wire-workers who make the moulds.

The second method of water-marking is that used on the machine, and it differs from the previous one in that the impression is made on the web after a good deal of the water has been removed and the web has become settled in place on the wire. It is carried out with the aid of a wire-covered skeleton drum made of brass and supported in brackets fixed to the wire frame. These brackets have a fine adjustment screw, so that the drum or dandy roll, as it is called, may be very finely adjusted upon the surface of the stuff. The roll

is always placed after the first or second suction box, so that the amount of water left in the web when it reaches the roll may be regulated.

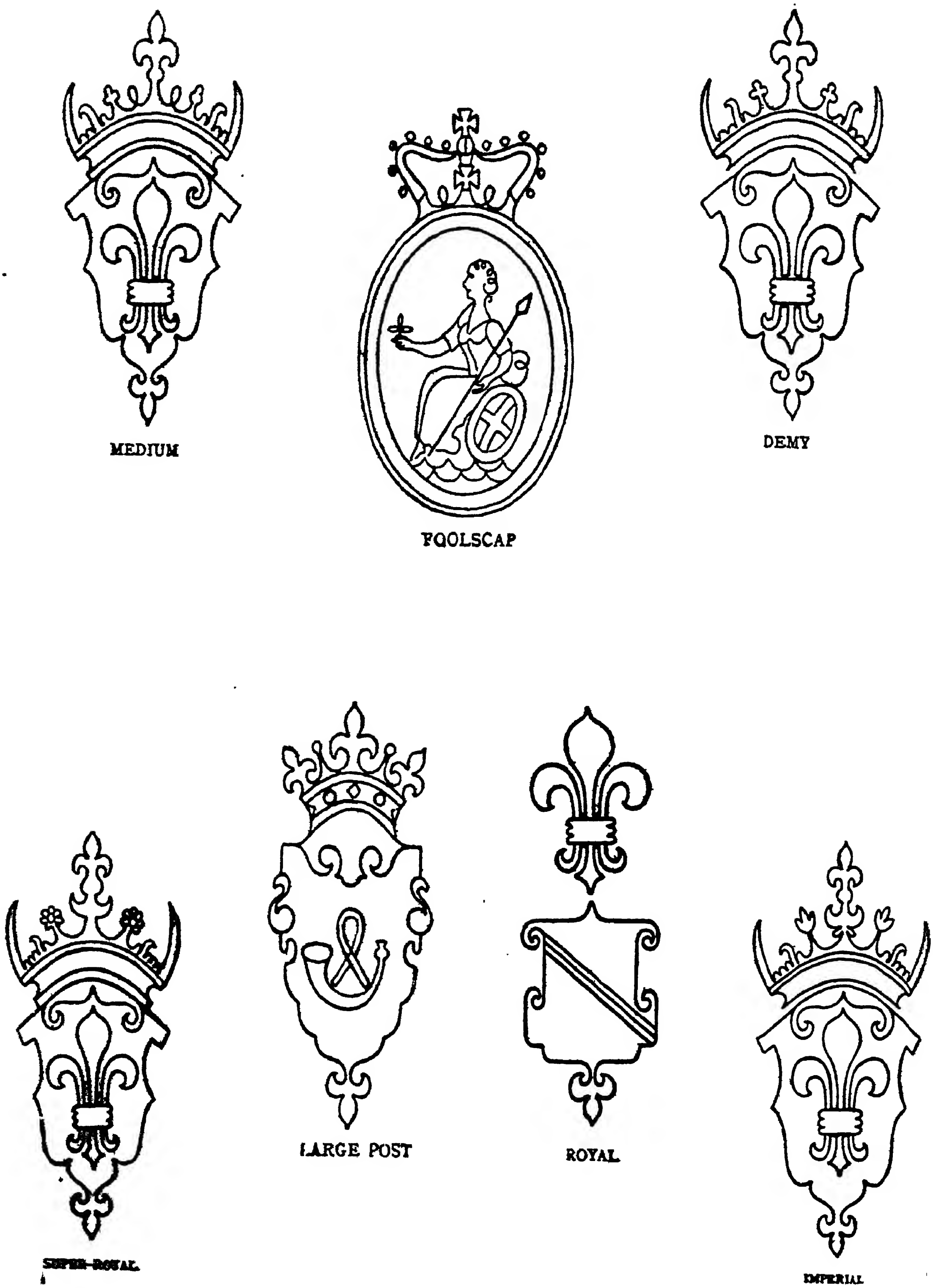
It is in the careful and skilful manipulation of the water in the web when the dandy roll touches it that the best results may be obtained, for if the web is sucked too dry, no mark will show, and if left too wet it will be crushed and 'worms' or 'tears' will appear in the sheet.

The dandy roll performs two distinct functions. First, it closes up the sheet, compressing the fibres together and generally improving the appearance or look-through of the paper, and for this purpose it is not necessary to have any design upon the roll; and, second, it is used for putting a name or device into the paper. In a plain 'wove' roll the skeleton drum is covered with fine wire cloth similar to the machine wire, and this roll does not actually water-mark the paper, but simply closes it up. Very high speeds may be attained on 'news' machines, using a plain wove dandy, provided the roll is of sufficient diameter and of correct weight and construction.

A different type of roll, and one used chiefly on ledger and thick writing papers, is known as a laid roll (Fig. 93, p. 228). This roll, instead of being covered with wire cloth, is covered with a collection of thick brass wires bound together at intervals of an inch or so by fine wires. Various gauges of wire are used, and thus the number of wires to the inch may be varied to suit the thickness or other characteristics of the paper. The thicker and stronger the paper, the coarser the wire used and the fewer the number of wires to the inch. Azure or blue papers look better with fewer wires to the inch than cream papers. A medium substance of ledger paper usually has about 18 wires to the inch, a writing paper about 20 wires and a thick, strong ledger about 16 wires.

Water-marking by means of a dandy roll is done by fixing a device or letters worked in wire on the cover of the roll, and this may be done on either a wove or a laid roll. The device stands out from the surface of the roll, and the weight of the roll presses the wires into the soft wet web, forcing the fibres away in all directions and thus forming a thin place in the web. When paper marked in this way is held up to the light, the device shows up as a translucent pattern.

Formerly, water-marks served as trade-marks for mills making the paper, and to a certain extent this still holds good, although probably the greater number of registered water-marks nowadays belongs to the wholesale stationers and printers. Some well-known devices are shown in Fig. 96. The marks vary from simple words of a few letters to the most elaborate and artistic designs—coats of arms, ships at sea, etc. Some very fine water-marking is done on papers for postage stamps and bank-notes, and, generally

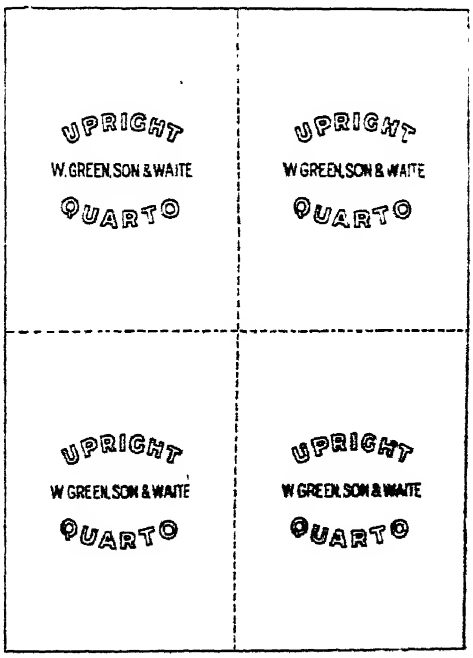


[*Blocks lent by 'The Paper Mills Directory.'*

Fig. 96.—Water-mark Devices used in Certain Sizes of Sheets

speaking, the finer and more intricate the design the slower the speed at which the paper has to be run. Many rolls containing intricate designs, and especially those having small round spaces enclosed by wire, are very troublesome on the machine, owing to the fact that they pick small pieces of stuff out of the web, causing holes to appear in the finished sheet.

By far the greater proportion of water-marks have to register in the finished sheet—that is, they have to fall in a predetermined position in every sheet when it is cut and ready for use. In order to achieve this the dandy rolls have to be made to suit different sizes of paper, so that they vary in circumference and also in the spacing of the names across the roll.



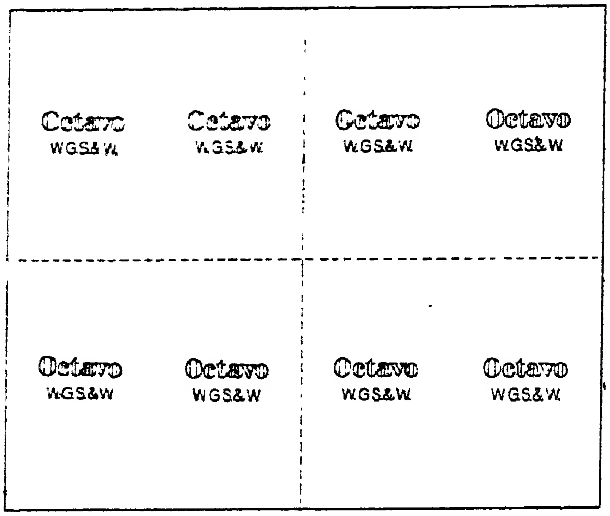
[*Green, Son and Waite*

FIG. 97.—SHOWING HOW THE WATER-MARK FALLS IN A LARGE POST UPRIGHT 4TO SHEET, 4 ON

The devices are either sewn or soldered on to the cover after being made separately, and when they are in position on the cover, all connecting wires used to hold the letters, figures or designs in place have to be removed. The designs are generally soldered on to the cover, and this is done by tinning the whole device before placing it in position and then running a soldering iron over it, causing the tin to run down and fix the wires to the cover.

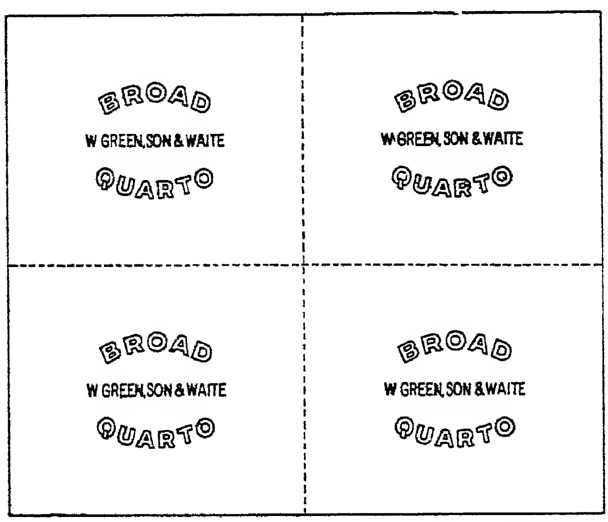
Since the web of waterleaf is drawn out in length—*i.e.*, in the machine direction—during the time it passes from the wire until it is dried, it will be obvious that the distance between the devices *round* the roll will have to be less than the distance desired in the finished sheet, and as the web shrinks in

the cross direction, the devices will have to be spaced out further across the roll than they are to be in the finished sheet. These variations must therefore be allowed for when ordering a roll for any particular size of paper. The variations remain fairly constant for each machine, but depend, of course, upon



[*Green, Son and Waite*

FIG. 98.—SHOWING HOW THE WATER-MARK FALLS IN A LARGE POST 8VO



[*Green, Son and Waite*

FIG. 99.—POSITION OF WATER-MARK IN BROAD QUARTO SHEET

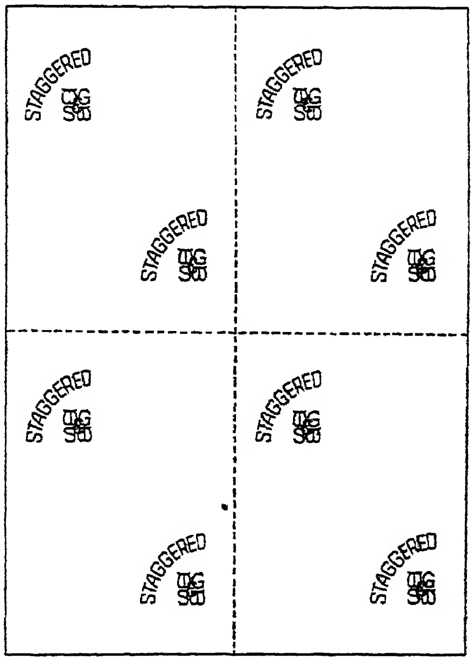
the 'draws' from the couch roll and presses, the heat of the first set of drying cylinders, and also on the nature of the stuff.

A roll for water-marking a sheet of Large Post, made 16½ inches across the machine, will have to be about 20¼ or 20½ inches in circumference and the

names will be spaced about 17½ inches apart; this will allow for a stretch of about ½ to ¾ inch down the machine and a shrinkage of about ⅝ inch across the machine for each sheet.

Figs. 97 to 100 show the positions of the water-marks in a sheet of writing paper.

Unless these matters are carefully attended to and the 'draws' carefully regulated, a great deal of broke will be made at the cutters, on account of the name or design not appearing at the correct and regular interval in the finished sheet. With papers for postage stamps and currency notes, where the water-marks have to register exactly and correspond minutely with intricate printings



Green, Son and Waite

FIG. 100.—POSITION OF MARK IN STAGGERED QUARTO SHEET

and perforating, special cutting marks are placed on the dandy roll, and the distances between these must be frequently checked by the machineman, at least after each beater is emptied, in order that any slight variation may at once be rectified by altering the draws or 'hanging' or lowering the dandy.

If the marks are coming too close, the dandy may be 'hung' or raised a little by lifting the brackets so that it drags on the stuff, or if the marks are too far apart the roll may be let down into close contact with the stuff. The roll is driven round entirely by the friction of the stuff, so that the amount of impetus given to it may be varied by the two methods mentioned. A third

way of increasing the drag upon it is to hang a felt cloth on it from above; this acts as a brake and reduces its speed.

None of these methods of 'dragging' the dandy roll is to be recommended. Both are inclined to cause 'pick-ups'. A far better way is to run a turn or two of tape round the ends of the roll. This will give a more regular distance, and if the paper is of thin substance will take the driving of the roll off the stuff a little and prevent 'pick-ups'.

CHAPTER XV

THE M.G. OR CYLINDER MACHINE—THE VAT OR BOARD MACHINE

THE M.G. machine (Figs. 101 and 102) is a modification of the Fourdrinier machine, designed to produce papers having certain distinctive characteristics as to surface.

The single-cylinder (or M.G.) machine is so called because it usually has only one drying cylinder in place of the tiers of cylinders arranged on Fourdrinier machines. It is sometimes called a 'Yankee' machine.

The wet end is exactly the same as that of the ordinary Fourdrinier, having chests, sand-tables, strainers, wire part, couch rolls and—in the case of ordinary machines—press rolls as well.

When the web leaves the press rolls it is led on to a felt, usually of special make, and this felt leads it into a nip between the large drying cylinder and a press roll or press rolls. The pressure exerted at the nip causes the wet web to stick to the polished surface of the hot cylinder, and it passes round the cylinder to the reel.

The cylinder is the most important part of the machine, is made of cast iron, or a mixture of iron and steel, chromium, etc., and is from 8 to 15 feet in diameter. The surface must be entirely free from blemishes of any kind if perfect paper is to be made, as any holes or depressions or flat places will seriously affect the surface of the paper. It should also be capable of taking on a good 'skin' or surface to which dust and fluff from the web will not adhere; or if it does adhere, should clean easily at the doctors.

The cylinder must at all times be absolutely clean and smooth if the beautiful mirror-like gloss, so necessary to the majority of M.G. papers, is to be maintained.

These large cylinders are no doubt very difficult to cast, but a really good one is worth almost anything to the mill which possesses it.

On most machines the cylinder is fitted with a hood or cover, which fits closely round the surface of the cylinder for about three-quarters of its circumference. Under this hood there are, on some machines, a series of steam-pipes so placed that they are very close to the web of paper as it passes

round the cylinder. Dry steam passes through these pipes and heats the moist vapour which is being driven from the web of paper by the heat of the cylinder. This assists the web to part with its water, and the vapour is drawn away from the hood by means of a large pipe and fan which exhaust to it atmosphere.

On other machines the hood has no steam-pipes, and the vapour is exhausted to atmosphere by means of a fan only. The process is really vacuum drying except that the vacuum is very low owing to there being no sealing of the joints between the hood and the cylinder.

There are two distinct methods of drying the web on these machines, which

[*Bentley and Jackson*

FIG. 101.—DRYING CYLINDER OF A LARGE M.G. MACHINE, SHOWING TWO PRESS ROLLS AND COMPLETE HOOD

have a marked effect on the finished paper, both as regards under side and surface.

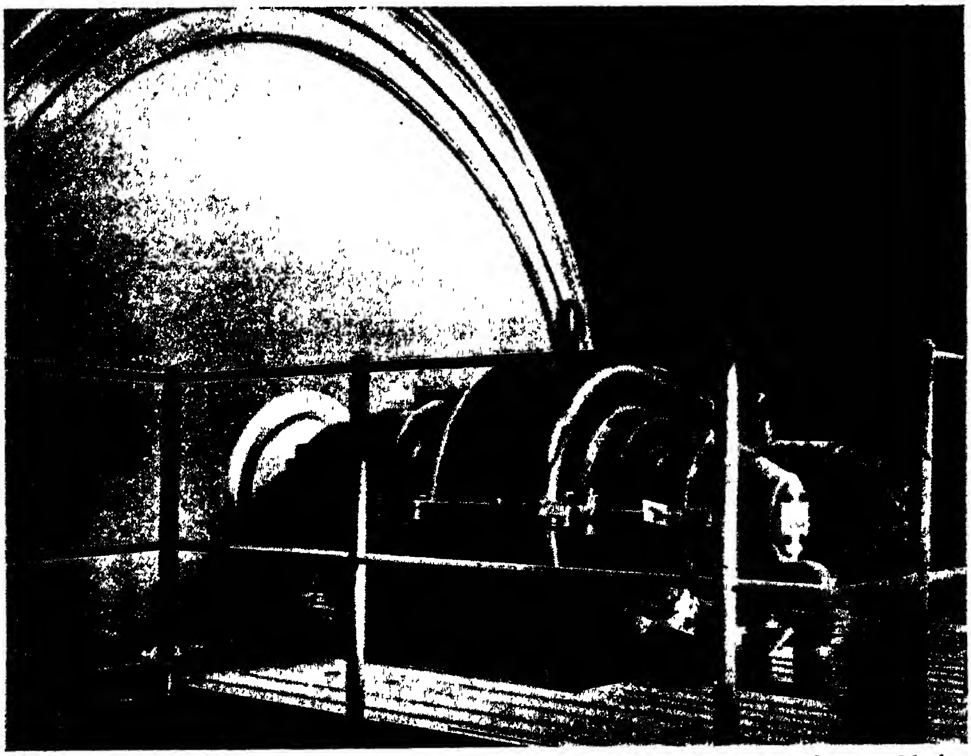
In one method the top side of the paper—that is, the side farthest away from the wire and wet felt of the machine—is brought in contact with the surface of the cylinder. In order to effect this, the web has to be led round the cylinder in such a way that it finishes up at the front top of the cylinder nearest the wet end of the machine, and immediately above the press rolls.

This method obviously gives the smoothest surface and the roughest under side.

The other method consists in leading the paper from the press back into contact with the cylinder—which is revolving clockwise or in the same direction as the wire—and in this case the *under side* of the web comes in contact with the cylinder and receives the smooth finish.

The result of this method is that the under side of the paper though 'finished' has not the close and highly polished surface of the paper made by the first method.

In order to modify the effects of these two arrangements and to suit the particular paper to be made, recourse is had to felts of various qualities. These felts, used to carry the web through the cylinder nip, are called 'overfelts',



[*Siemens Schuckert*

FIG. 102.—ELECTRIC DRIVE FITTED DIRECT TO JOURNAL OF A LARGE M.G. CYLINDER

and may be had either rough, smooth, thick or thin, ribbed, striped or plain, according to the effect it is desired to produce in the finished paper; they are made of wool. The finish obtained depends on a variety of circumstances, but chiefly on the surface of the cylinder, as has been stated above.

The press roll which squeezes the web into contact with the cylinder is worked by means of compound levers and weights, and it has to be very rigid to stand the strain and prevent it from springing in the middle and thereby reducing the pressure on the web.

Opinions differ as to the best position of this roll, but it is usually placed

exactly under the centre of the cylinder, so that the nip given to the web of paper and felt is as direct as possible.

These press rolls were at one time made of iron, but they are now more generally covered with rubber, as they give almost equally good results and are much less hard on the felts.

On some machines the press roll is placed either in front or behind the centre of the cylinder, so that the pressure of the weighted lever does not press directly to the centre of the cylinder, but to a point between the centre and the circumference, and has a dragging action. Our experience has led us to favour the former method, and we are of opinion that the paper must stick instantly to the cylinder and remain fixed in close contact with it during the whole of the time it is passing round.

On other machines two cylinder press rolls are fitted, but we cannot understand the necessity for these, in spite of the fact that they are presumably giving good results, and they are being fitted to some of the latest machines. It would appear to be highly probable that the second press roll to come in contact with the web would interfere with the work done by the first one, in sticking the web to the cylinder.

We believe that two press rolls are the cause of a lot of trouble on M.G. machines. It is asserted that by having two rolls the pressure on each can be varied at will to suit the special requirements of the paper being made. We think this is very doubtful.

The overfelts are usually washed continuously after they leave the press roll, or if no washer is available they are sprayed with cold water to cool and clean them before they again come in contact with the web.

An important factor in determining the finish of both sides of the paper is the amount of water left in it at the wet press rolls. If a good finish is required, the web should be fairly moist on reaching the cylinder; and if a pronounced rib or stripe is required, or a rough under side, the wet press rolls should be let down very lightly or they may be hung up altogether. This will leave the web bulky and impressionable, so that the full effect of the overfelt can be produced.

The furnish of the paper and the way it is beaten have, of course, a very marked effect on the finish, as obviously very long and wild stuff will not take on such a good finish as finer stock, or a common brown as will a pure sulphite.

The state of fibrillation or wetness also has another important effect, in that if the stuff is *too wet* it may be impossible to get it to stick to the cylinder at all.

For kraft papers and sulphites it is usual to try to get the highest possible finish, while for lithos and certain other papers too high a gloss is not desirable.

It may be taken as a general rule that the purer the furnish used the easier will it be to keep the cylinder clean, and the making of common papers from refuse containing grit, oil, tar, etc., is very detrimental to the surface of the cylinder, as is also the use of bleached pulp from which the bleach residues have not been properly removed.

It has already been stated that about three-quarters of the cylinder is used for drying the paper; the other quarter is taken up by the cleaning and polishing apparatus, which must always be in as accessible a position as possible, in order to facilitate the changing of doctor blades, wire brushes, etc.

The principal piece of apparatus for keeping the cylinder clean is the ordinary doctor, preferably a Vickery, and there are usually two of these. One is fitted in position just before the cylinder comes in contact with the web at the press and the other one immediately after the paper has been pulled off the cylinder. This latter doctor removes the end of paper which comes over first, prior to its being wound on to the reel.

Between these two doctors may be fitted all kinds of cleaning devices to suit the individual tastes and fancies of the paper-maker.

Another effective burnisher is a stiff wire brush, made by winding carding cloth round a wooden roll, and nailing it in position. The roll is driven at a high speed (250 revolutions per minute), the wire bristles cleaning and polishing the surface of the cylinder.

A wooden doctor covered with a piece of damp felt is also used, and this is very effective in damping the fluff and dust which dry on to the cylinder, thus enabling the steel doctor blade to remove them. The felt may be frequently changed if necessary.

A 'water' doctor is also very effective; it consists of a perforated pipe, which forces wet steam against the surface of the cylinder immediately in front of the iron doctor blade.

Apart from these devices for keeping the cylinder clean while it is in motion, it is also necessary periodically to grind it or buff it, or it may be cleaned with emery powder and oil. For grinding it, a perfectly true iron roll is fitted in position in place of the press roll, and driven at a higher speed than the cylinder by means of very tight belts in the presence of water.

This is a risky business, for unless the belts are kept *very tight all the time*, the motion of the cylinder will be bumpy and will result in flat places being formed, which will show on the surface of the paper later.

The best way to carry out this work is to buff the cylinder with proper buffing apparatus.

When the cylinder has to be stopped for any special cleaning, it should first be allowed to cool down, as the dirt is then more easily removed.

If soft water is available for paper-making, it seems to be much easier to keep the cylinder clean than if the water is very hard.

The papers made on M.G. machines are very varied in character and uses, and the following are some of the most common: Pressings, manillas for envelopes, litho papers for poster work, krafts, sulphite bag papers, common cap and cheap wrappings, tissues and sealings.

The machine described is the commonest type, but there are many variations and modifications, of which the following are a selection:

1. An ordinary Fourdrinier wet end, followed by several small drying cylinders, which partly dry the paper before it is led to the large cylinder. The overfelt of this machine receives the paper from the last of the small cylinders, which are not usually very hot, and takes it to the cylinder press. The felt is damped just before the press nip.

This arrangement enables higher speeds to be run, as the big cylinder is relieved of some of the drying, and it does not have any detrimental effect upon the high surface which is obtained on the paper.

2. The 'lick-up' machine may have either a vat or Fourdrinier wet end, but it does not possess a wet press. Instead, the wet felt passes round the top couch rolls, and the web is transferred to it at the couch, carrying it to the cylinder press and depositing it on the cylinder. The felt acts as wet felt and overfelt, and is usually passed through a washer to cool and clean it on its return journey from the cylinder to the couch roll. On this type of machine the *under side* of the web sticks to the cylinder and receives the polished surface.

If the wet end is of the vat type, as described in the following section, the web is made on the wire drum and transferred to the wet felt and thence to the cylinder.

3. A combination of both the above-mentioned types makes duplex paper in the following manner: The Fourdrinier wire part forms one side of the sheets and the other side is made on a cylinder mould situated above the wet end. The second web is led by a felt into the couch of the Fourdrinier wet end and the two webs are united, couched and pressed together at the same time, thus forming a duplex sheet or thin board. They are subsequently dried on the cylinder in the usual way.

4. Heavy boards may be made by having a battery of cylinder moulds exactly the same as those for the ordinary board machines, as described in the following pages.

It will be readily understood that the drying power of an M.G. machine is very limited compared to some Fourdrinier machines with their long double tiers of drying cylinders. For this reason it is usual to work the cylinder very hot indeed, as hot as the paper can stand without blistering.

Except in the case of very thin papers, high speeds cannot be attained, and for this reason better prices are usually obtained for M.G. papers than for similar qualities supercalendered or unglazed.

THE BOARD OR VAT MACHINE

This important paper-making machine is very different from the Fourdrinier machine in the manner in which it makes or forms the web of paper, but it is the same as the Fourdrinier machine from the presses to the calenders.

The simplest type is the single-vat machine, which has no drying cylinders and is used for making very thick boards. It works as follows:

The pulp is pumped from the stuff chests to the stuff box and thence to the strainers; it then flows to a vat or trough, in which revolves a bronze cylinder, hollow in the centre and open at the ends, and with a covering of fine-mesh machine wire cloth over a stout backing wire.

The construction of the cylinder is much the same as that of a wove dandy roll. As the cylinder revolves about two-thirds immersed in the stuff, the water in which the fibres are suspended rushes through the meshes of the wire in the same way as it runs through the wire on the wet end of a Fourdrinier machine. As, however, the meshes are too fine to allow the passage of the fibres, the latter cling to the surface of the wire drum, and thus a thin film of fibres is formed on the revolving mould.

As the drum moves round towards the top, the film of stuff is lifted clear of the stuff and water in the vat, and more water drains away. When the wet film reaches the highest part of the circumference of the roll it comes in contact with an endless travelling wet felt. As the web touches the wet felt it is couched by means of a felt-covered wooden roll, which presses the travelling felt against the surface of the drum. In this way the wet film of pulp is picked up from the wire surface and adheres to the felt.

The felt carries it along to squeezing or press rolls, where it is relieved of as much water as possible. The web sticks to and is wound round and round the top press roll until a sufficient thickness has been formed. This is indicated automatically by the ringing of a bell. It is then cut off by hand, laid in a pile, pressed and finally dried by hot air.

The resulting paper is known as a board, and such boards are used for boxes, panels, suitcases, etc. Larger machines are provided with drying cylinders and calenders for drying and glazing the board as it is made. By using two stuff chests, two sets of strainers and two vats, a board can be made of two different qualities of colours—that is to say, it may consist of common brown paper stuff on one side, and have a white top side made of sulphite

pulp, or of stock of any colour. Such papers are known as duplex, which means that they are two-sided or two-ply. The width of the web which is to be made on the drum is regulated by stopping up the meshes of the wire by tapes, which may be wound on at either side. This obviously has the effect of closing the meshes of the wire cloth, so that water cannot run freely through and cause the formation of a web of fibres.

The water which passes through is run away to a back-water box, whence it is pumped back again for further use in furnishing the beaters. The thickness of the web which will form on the cylinder is obviously limited, for, as it becomes thicker, less and less water can pass through, and so the number of

[*Banning and Seybold*

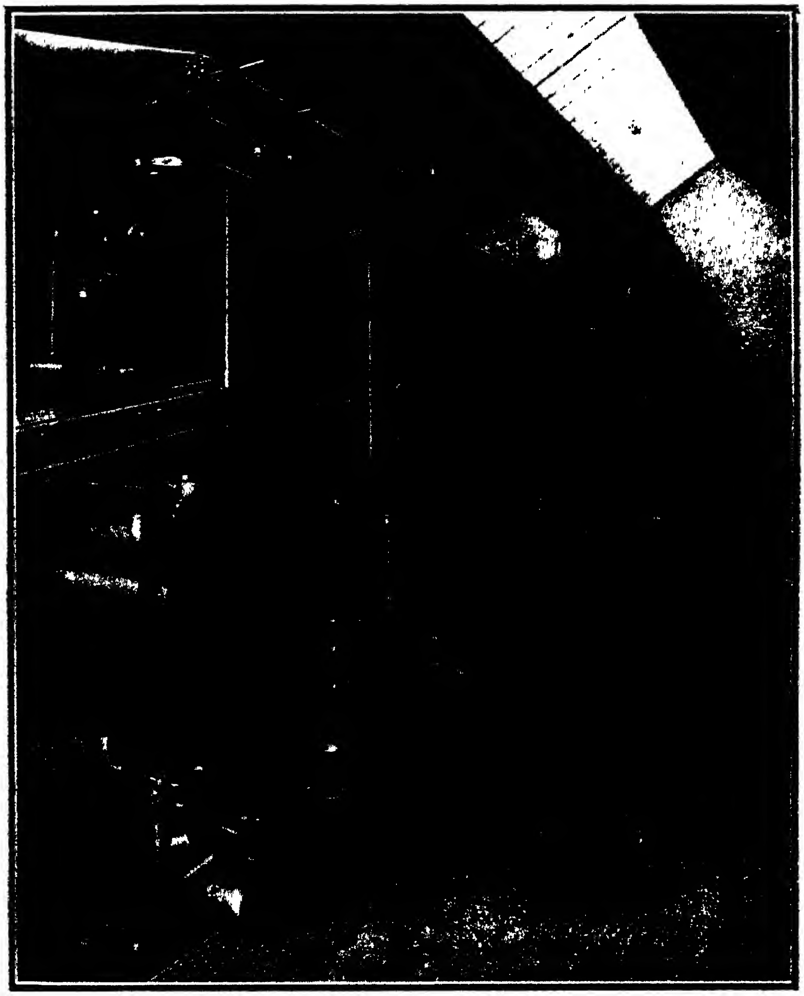
FIG. 103.—SHEET-FORMING VATS OF A MULTIPLE-VAT BOARD MACHINE

fibres deposited becomes less. The thickness of the various webs which form the board is regulated by the consistency of stuff going to the vat, and by the speed of the machine.

In order, however, to produce a thick board suitable for making folding boxes, or a paper which has to be very thick and stiff, the number of vats and making drums may be increased to four or even six or eight, and all the webs pressed together to form one thick sheet (Figs. 103 and 104).

In this way boards may be made with a different-coloured surface on each side and with a 'middle' of entirely different colour and quality. To do this it will be seen that different sets of beaters will be required, also a number of stuff chests, mixing boxes, and strainers, to correspond with the number of qualities of stuff to be used to compose the finished board.

Each chest requires a separate stuff pump, and where stocks of different colours are being used, separate back-water pumps and tanks are needed to pump back and store the water from the vats for the beaters or mixing boxes. From the foregoing it will be gathered that the wet end of a multi-vat machine is a somewhat complicated and costly affair.



[*Masson, Scott and Co. Ltd.*

FIG. 104.—VATS AND COUCH ROLLS OF A MULTIPLE-VAT BOARD MACHINE

To take the case of a four-vat machine: The vats are arranged close together, and in rotation, the first one to deliver its web of stuff to the wet felt being the one nearest the presses, and so on in a reverse direction towards the strainers. When the fourth web has been picked up, the felt will be fairly heavily loaded, and here it turns round a roll and travels back towards the presses of the machine carrying the four-ply web on top and immediately above the vats.

The presses at first are small and fairly light, and are placed in rotation, in steps, leading down to the main heavy press roll. These small presses are generally called 'baby' presses (Fig. 105), and they serve to squeeze and incorporate the four webs of paper together gradually before the main pressure is applied by the heavy press, which is usually of granite.

The 'baby' presses are of wood or metal, and are usually from five to seven in number; the web passes straight through them and is not reversed. At the

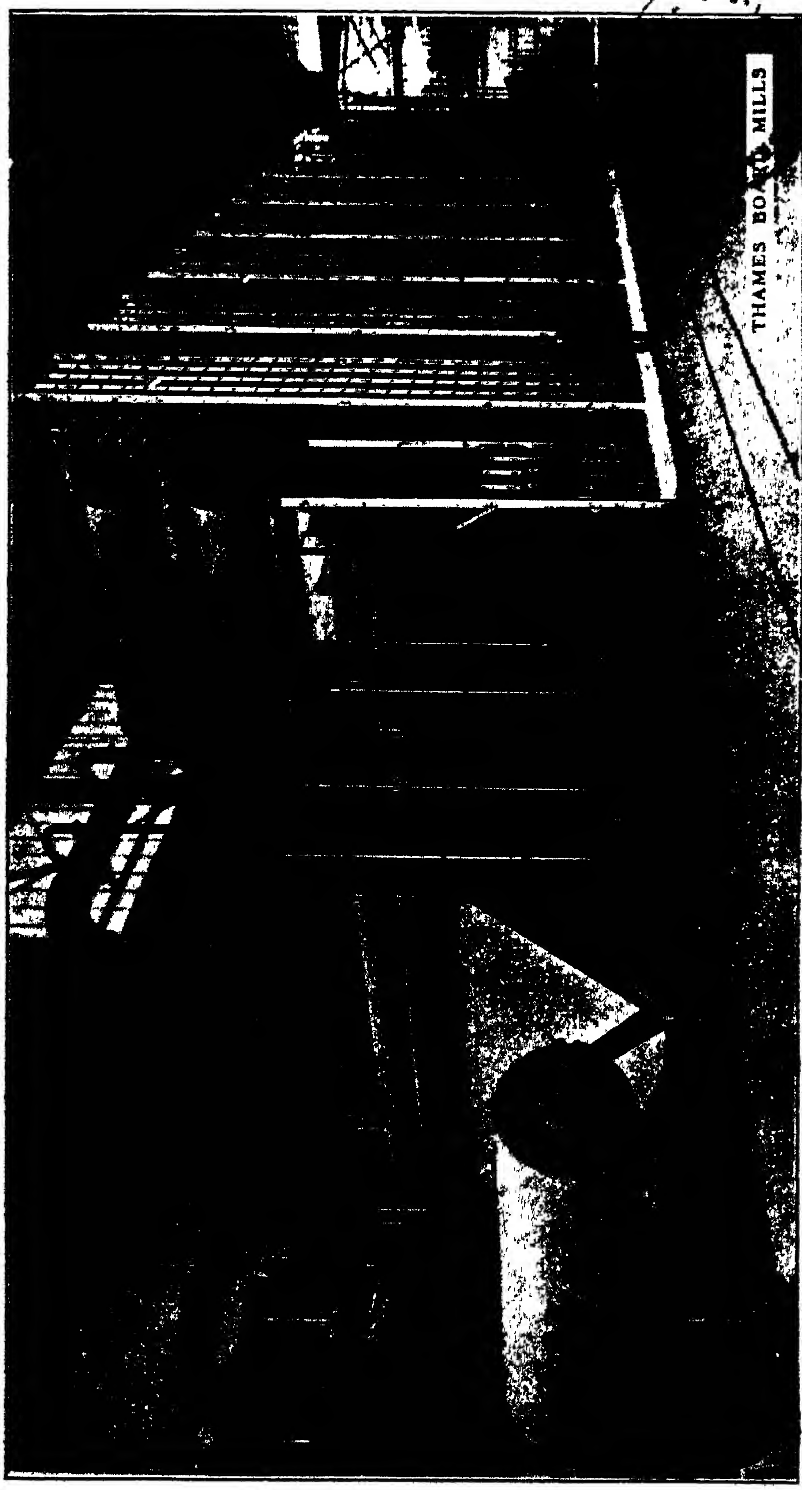
[*H. J. and A. Coulthurst, Ltd.*

FIG. 106.—A BATTERY OF CHESTS FOR SUPPLYING STUFF TO THE VATS OF A MULTIPLE-VAT BOARD MACHINE

'baby' presses another felt comes into action and is in contact with the upper side of the paper during its passage through them.

The wet felt carries the web right to the main press roll; this wet felt passes through a felt washing-tank and squeezing rolls before returning to the vats to pick up a further web of paper.

The majority of papers made on board machines are either 'duplex' or 'triplex', the former having, as a rule, a face of pure sulphite and a back of a



[*Courtesy Walmsleys (Bury) Ltd. and Thames Board Mills*

FIG. 107.—STACKED DRYING CYLINDERS, CALENDERS AND REEL-UP OF A LARGE BOARD MACHINE

mixture of mechanical pulp and waste papers, the proportions being 25 per cent face and 75 per cent backing.

In the drying of boards it is not the general practice to use dry felts, and on some of the big modern machines, in order to save space, the drying cylinders have been arranged in tiers, five or six high. We believe that this practice originated in America, but we are not at all certain that it is an unqualified success.

It is almost universal practice to combine a system of hot air with the dry cylinders, in order to absorb the large amount of moisture given off into the pockets between the tiers of the cylinders, and between the cylinders themselves.

On many board machines the paper is calendered on machine calenders, and then cut at the end of the machine, instead of being reeled and cut separately.

This is not, as a rule, a difficult matter, as board machines run at a comparatively slow speed when compared with some modern paper-making machines, although, of course, the output in weight may be very high.

In the case of triplex boards the usual furnish is face and backing of the same material, such as sulphite, with a middle of poorer quality, such as strawboards and mixed waste papers.

This arrangement necessitates the use of only two sets of beaters and chests, a great saving of space and power. The usual 'finish' is a water-finish put on with chilled iron rolls in two tiers on to which water is led from a trough. Soap is usually added to the trough to prevent rusting. The paper passes from the second stack moist, and the finish is put on during its passage through the two remaining stacks. Four stacks of calenders have therefore to be provided.

The 'Mould' Machine

The so-called mould machine is used for making imitation hand-made papers, and papers made on these machines are the nearest approach to hand-made paper which has yet been achieved by mechanical means.

The paper is, however, inferior to genuine hand-made paper.

It is possible on this machine to make paper with a deckle edge all round the sheet, and this fact alone is liable to mislead those who are not experts into mistaking the 'mould' made for the real hand-made sheet.

Great secrecy is observed in mills possessing these mould machines; the wet end, consisting of strainer, vat, wire-covered cylinder and presses, is placed in a locked room, and the wet web is led on a felt through a slit in the wall into the drying room.

The 'mould' or cylinder is just like a large-diameter dandy roll, and it revolves partly submerged in the stuff in the vat.

This roll has the devices and lettering, etc., fixed to its woven-wire cover, and as it revolves it picks up a layer of stuff, thick where the cover is plain cloth, and thin where the device wires are placed.

The wet film of stuff is couched off at the top and taken on a felt to the presses in exactly the same way as the stuff is couched off the drum of a board machine.

If the paper is to be made in single sheets, strips of wire are placed round and across the roll to fix the dimensions of the sheet. No stuff, or very little stuff, adheres to this wire, so that when the wet sheets have been pressed they come apart, or are easily pulled apart by hand, leaving a 'deckle' edge.

The machines are so arranged, and fitted with four or five or more drying cylinders, that the paper may either be dried at once by steam, or may be removed from the felt by hand as wet waterleaf and dried by air in a loft.

The Richardson-Key expanding cylinder 'mould' is sometimes used on these machines, owing to the ease with which a new wire cloth cover may be fitted when changing from one water-mark or size to another. This patent 'mould' enables a great saving to be made in the stock of 'moulds' or drums, which would otherwise have to be carried.

Two and Multiple Wire Machines

In recent years increasing use is being made of Fourdrinier machines with more than one wire. The object of this is twofold. In the first place it enables a paper to be produced with two top sides on which to print. This is achieved by running together the under or wire sides of two thin papers, leaving the two top sides outermost. It is thus possible to produce a printing paper with exactly the same surface on each side of the sheet. The method is also applied to make paper of very great strength, and two or more wires may be used for this, giving a two- or three-ply sheet. Some mills have been doing this for a long time, but the practice has not been general. More frequently a Fourdrinier wire has been used in conjunction with a vat such as that used on a mould machine, but now that the difficulties of combining the two sheets at the press have been overcome, the use of two complete Fourdrinier wire parts to form the sheets is quite common practice. The sheets are brought together at the press, where they become homogeneous and pass on through the second and third press and across the dryer as one solid sheet.

It is not, of course, possible in this case to make satisfactory laid or water-marked sheets.

CHAPTER XVI

THE MANUFACTURE OF NEWSPRINT

PRODUCTION FIGURES—FIBROUS RAW MATERIALS—NON-FIBROUS RAW MATERIALS—HANDLING OF RAW MATERIALS—WATER—PREPARATION OF ALUM, LOADING, AND DYES FOR ADDITION TO STOCK—PREPARATION AND PROPERTIES OF STOCK—STRAINERS AND SLICE—THE WIRE PART—THE PRESS PART—THE DRYER PART—FINISHING—FUTURE TRENDS OF NEWSPRINT MANUFACTURE

IN the descriptions of paper-making practice given in other chapters (notably in Chapters XI, XII and XIII), there is a good deal of information which is applicable to the manufacture of newsprint. Nevertheless, since newsprint-making has tended to become increasingly specialised—if only because of the ever-growing necessity for reducing conversion costs by the development of larger output machines running at high speeds—it will be useful in this chapter, not only to give a brief general discussion of the technique of this branch of paper-making, but also to draw attention to various aspects of it which are peculiar to newsprint. The subject is treated primarily from the viewpoint of the manufacturer in this country who does not prepare his own pulp, but purchases it ready-made. Some details of the processes for pulping wood for making newsprint are, however, given in Chapter V (see pp. 55, 61, 68 and 69).

Production Figures.—World production of newsprint in 1938, the last complete year uninterrupted by war, was 6,710,000 long tons. The greatest quantity yet manufactured in a single year was 8,020,000 tons, which was the world output for 1937. The world production of paper of all kinds for 1937 was 20,500,000 tons; thus newsprint accounts for about 40 per cent of this total.

These figures give some idea of the importance and size of the world's newsprint industry.

Even more striking, perhaps, is the rate at which the annual production of newsprint has increased. In Canada, for instance, to take an outstanding example, the production in 1913, the year immediately preceding the last war, was 310,000 tons. In the peak year of 1937 the production rose to 3,250,000 tons—a tenfold increase. Enormous expansions of this kind have

been made possible not only by building new mills, but also by increasing the size, the speed, and the efficiency of the machines used to make this class of paper. Newsprint manufacture has, in fact, been largely responsible for leading the industry with ever wider and faster machines. This, of course, is a logical development, since newsprint must always remain one of the cheapest grades of paper made, and it is also required in quantities that far exceed any other class of paper.

The majority of modern Fourdrinier newsprint machines in operation to-day are designed for maximum paper widths ranging from about 200 to 250 inches, but a notable exception is the world's largest machine, which makes paper 304 inches wide. This is an all-British machine operating in England.

The most common speeds of modern newsprint machines range from about 1050 to 1250 feet per minute, while the highest authentic speed is in the neighbourhood of 1400 feet per minute. Machines of this kind naturally produce a lot of paper. The output of the 304-inch machine, for example, when making super-calendered paper of normal substance (55 grams per square metre), reeled and ready for the customer, exceeds 200 tons per 24 hours.

The fibrous raw materials for newsprint are prepared exclusively from wood, and it takes, very roughly, a cord of wood to produce a ton of finished newsprint; a cord being a pile of logs, all lying parallel to each other, 4 feet high, 4 feet wide, and 8 feet long. A cord of wood corresponds, very approximately, to eight trees having an average height of usable trunk of about 50 feet, and an average diameter of about 18 inches. Calculating from the basis that a typical pre-war daily newspaper of about sixteen pages weighed 4 oz., the amount of pulp required for a circulation of two million copies was over 200 tons (air-dry) per day. This means that rather more than 800 trees had to be cut down every day to satisfy the requirements of only one of the leading newspapers published in this country.

Altogether, the average daily consumption of newsprint in the British Isles during 1938 was 3400 tons, the consumption for the year having reached the total of 1,241,000 tons. The corresponding annual consumption per head of the population was about 60 lb. It is interesting to compare these figures with those for North America (Canada, U.S.A., and Newfoundland). The total consumption for the same year, 1938, was 3,088,000 tons, which gives a daily consumption of 8500 tons. Although these figures are two and a half times greater than the figures for this country, the consumption per head in North America was somewhat lower, being about 53 lb. per year. During 1938 the British Isles and North America together accounted for 62 per cent of the world production of 6,710,000 tons.

These enormous tonnages give some idea of the inroads being made into

the forests of the world to satisfy the demand for newsprint. The question of the continuity of wood supplies has, as a result, given rise to some anxiety, and from time to time it has been concluded that the world is in sight of a serious shortage. Although these scares appear to have been unjustified, they have at least drawn attention to the need for organized schemes of wood-cutting and afforestation to ensure that, with steadily increasing demands, the wood supply is maintained. Nearly all the major wood-pulp producing countries, and especially the European ones—Norway, Sweden, and Finland—have their forests continuously surveyed, in order to check consumption against the annual rate of growth. As a result the necessary afforestation measures are enforced.

Fibrous Raw Materials.—By far the most common variety of wood used for newsprint manufacture in Europe is spruce (see p. 50). This wood is converted both into groundwood (mechanical pulp), and also into sulphite pulp. Very exceptionally sulphate pulp is used. Groundwood is the most inexpensive fibrous material (other than waste paper) available for newsprint, but apart from this advantage it is particularly well-suited for newsprint production. It has the necessary absorbent properties to take the printing-ink well, and it has good opacity. In fact, it has often been said, quite rightly, that to obtain the best printing results it would be preferable to use groundwood alone. In practice, however, a proportion of pulp, longer fibred than groundwood, is necessary, mainly to help the immature sheet to have the requisite strength to be carried on its journey along the paper machine, from the couch, through the presses to the drying cylinders. The pulp most commonly used for this purpose is known as news quality, or strong, sulphite pulp. Occasionally sulphate pulp is preferred to sulphite pulp, but its selection is justified only on those rare occasions when it is cheaper than sulphite pulp, due to exceptional market conditions, or because a newsprint mill is in close proximity to a sulphate mill where supplies of pulp may be available in slush form at a competitive price. Actually sulphate pulp has the advantages of a somewhat longer fibre than sulphite pulp, and it is free from resinous subtances. On the other hand, even in the palest grades, it is usually rather darker in colour than strong sulphite pulp, which is an objectionable feature if bright, nearly white shades are required, as is mostly the case nowadays in this country.

At the present time the proportion of chemical pulp used with groundwood for a newsprint furnish ranges from about 10 per cent to 20 per cent. Some years ago the amount commonly used was as high as 30 per cent, but, partly due to the need for retrieving some profit out of the ever-decreasing selling price of newsprint, and partly due to a growing understanding of the

importance of groundwood for giving good printing qualities, the sulphite percentage has been steadily reduced. Improvements in groundwood manufacture, resulting from scientific research, and also the development of reliable methods of pulp evaluation, have helped to make the reduction in sulphite content practicable.

Non-Fibrous Raw Materials.—Mention must be made of the two other raw materials that occur in appreciable proportions in newsprint. They are loading and water.

Loading is added to newsprint to increase ink receptivity, to help to give satisfactory opacity, and to fill up inter-fibre spaces so that a smoother surface may be obtained; it also helps to make a sheet of paper as economically as possible. China clay is the most common loading for newsprint, although in some American mills calcium carbonate is used, because china clay is expensive; the reason being that it occurs only to a limited extent in the United States, and a good deal has, therefore, to be imported from Cornwall. In one American mill, calcium carbonate is made from carbon-dioxide recovered from the flue gases of the boiler plant. In other mills, loading is not used at all, because of the expense of transporting it to the mill site.

The cheaper grades of clay, even down to mica clays, are quite satisfactory for newsprint, provided the abrasive grit content is not too high. This is an important point to watch, otherwise excessive wire wear may result. The colour of the clay, unless it is exceptionally bad, has no appreciable effect on the shade of the finished newsprint paper, and it is, therefore, only a secondary consideration. The amount of loading carried may range from 2 or 3 per cent up to 12 per cent or more, depending on the properties desired, the basis weight of the paper, and other factors.

The last of the four major constituents of newsprint, water, is the cheapest, but it is by no means unimportant, neither is it put in primarily for reasons of economy. Newsprint devoid of water would, like any other paper, be of very inferior quality. The presence of the correct amount of water, which should be between about 8 per cent and 10 per cent, is helpful in obtaining a satisfactory finish; it gives paper a mellow handle (if it is too dry it will be harsh and brittle; if too wet it will be soft and flabby); it minimises the possibility of troubles due to static electricity during printing, and it reduces the tendency to cockle during transport and storage.

The analysis below gives the proportions in which the four constituents mentioned occur in a typical sample of newsprint.

Groundwood	70%	or 84%	expressed as a percentage of the fibrous furnish only
Sulphite pulp	13%	or 16%	
China clay	8%		
Moisture	9%		

Handling of Raw Materials.—Raw materials for newsprint are required in large quantities, and therefore up-to-date methods of handling and transporting are an essential part of a modern mill. It is of prime importance that the site should have good rail and water transport facilities; and, in addition, road transport is essential, as it is used almost exclusively for the distribution of paper to customers in this country. It is also used for conveying general stores, machinery and the less bulky raw materials, such as dyestuffs, to the mill.

A well-located newsprint mill, producing, for example, 3000 tons of paper per 5½-day week from four modern machines, will consume approximately 4500 tons of moist mechanical pulp, 500 tons of air-dry sulphite pulp, 300 tons of china clay, and 2000 tons of coal per week, all of which will be delivered by ships carrying anything from 1000 to 5000 tons or more of cargo. These ships come alongside the mill wharf for unloading. Coal and china clay are grabbed out by the wharf cranes and discharged direct into the bunkers provided. Pulp is lifted from the ship's hold, usually four or five bales at a time, on to trucks belonging to the mill, and the bales are tidily stacked subsequently, using gantry cranes.

Coal is conveyed into the mill continuously by bucket or belt conveyors, and clay is usually slurried in a building integral with the clay bunker, the slurry being then available for pumping to the point at which it is mixed with the stock in the mill. Pulp is reclaimed from the stacks by the mill gantry cranes and taken to the beater floor, either by electric trucks or in some cases direct by crane.

The handling of newsprint raw materials has been specially mentioned in order to emphasise the important point that with only a relatively small margin between raw material costs and the selling price of the finished product, conversion costs, which of course include the cost of handling materials, must be kept to the most economical level possible. Newsprint to-day is essentially a cheap product, mass-produced in enormous tonnages. Every effort must, therefore, be made to ensure that labour is not wasted by inefficient methods of handling materials.

Water.—The water supply for processing the paper is obtained usually from wells, although in some cases it is drawn from rivers. River water often requires rather elaborate flocculation and filtration treatment, but well water has the advantage that it rarely needs any treatment at all. The quantity required for all paper-making purposes will be of the order of 12,000 gallons per hour per machine, which, at 6 tons per hour production per machine, is 2000 gallons of water per ton of paper manufactured. Of this quantity the dryers will evaporate about 2500 gallons per hour, the remainder being necessary to make up incidental non-recoverable losses, such as hosing floors, machine wash-ups,

[*Stothert and Pitt, Ltd., Bath*

FIG. 109.—$2\frac{1}{2}$-TON CRANES USED FOR UNLOADING PULP, COAL, AND CHINA CLAY DIRECT FROM OCEAN-GOING SHIPS

The pulp bales are loaded on to trucks for subsequent stacking by gantry cranes

and water drained away from the presses. For safety a supply should be available considerably in excess of this rather economical quantity of 2000 gallons per ton. It should, however, be the aim to keep the water consumption on the machines to as low a figure as possible, not so much because water may be difficult to obtain, as because extravagance will almost invariably be linked with excessive fibre losses. Modern newsprint manufacture calls essentially for a closed back-water system, which means that as large a quantity as possible of the water should be used over and over again. Any water added in excess of that subsequently removed by the machine (principally at the dryers) will be wasted water, and unless an efficient fibre recovery system is available, the loss involved is likely to be serious. With an adequately balanced water system, a recovery unit is not, as a matter of fact, essential.

The quality of the water used for the actual paper-making process, as distinct from the boiler plant, is not of material importance. It should, of course, be clear, and free from suspended matter, but it may be very hard without giving any serious paper-making troubles. Indeed it is contended in some mills that hard water has certain definite advantages over soft water, such as helping to prevent pitch troubles on the machines. A typical hard water, quite satisfactory for newsprint manufacture, is as follows:

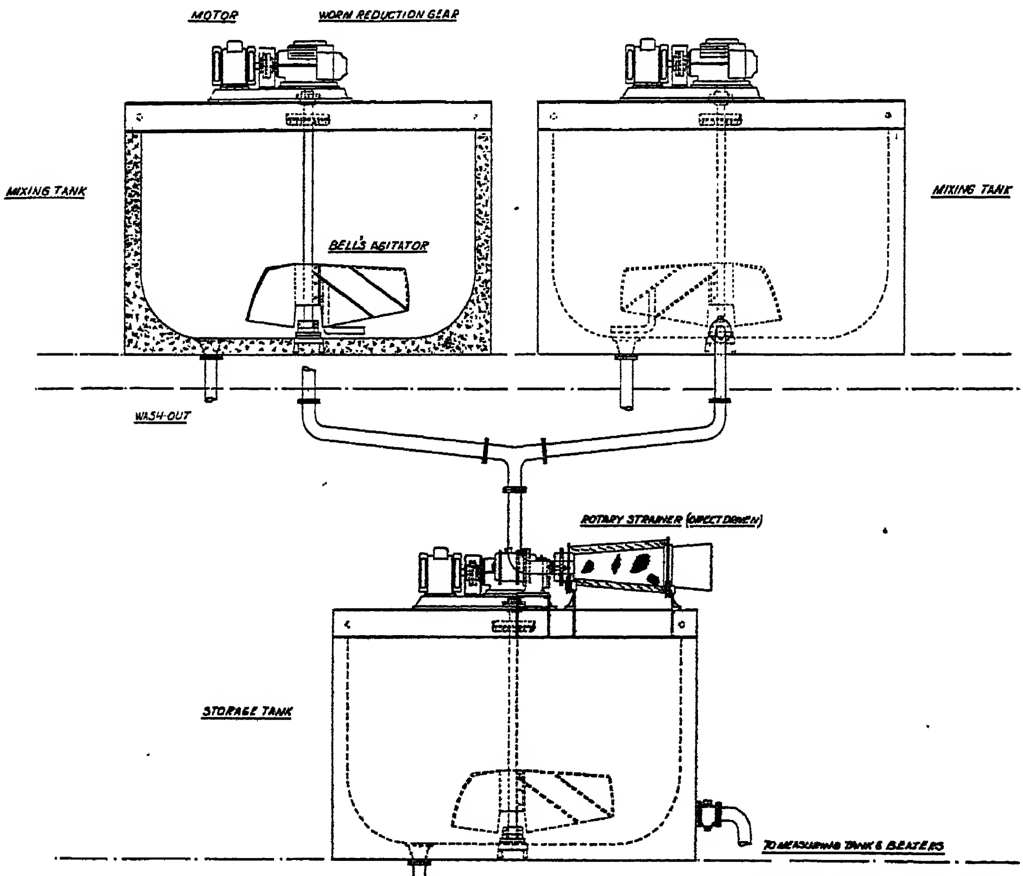
Ca	9.7 parts per 100,000
Mg	3.2 " " "
Cl	9.6 " " "
SO_4	2.1 " " "
Hardness, permanent	10.0 " " "
" temporary	27.2 " " "

Preparation of Alum, Loading, and Dyes for Addition to Stock.—The most efficient practice in newsprint mills to-day demands that all the auxiliary materials, loading, alum, and in many cases dyestuffs, should be added to the stock in suspension or in solution.

China clay, as already mentioned, is mixed into a slurry with water, in the clay-mixing house, which should be adjoining the clay store. The clay is mixed in tanks, fitted with the necessary agitator gear, to give a concentration of about 2 lb. per gallon. From the mixing tank the slurry is pumped through a screen, usually made of old machine wire, to a storage tank. The slurry must, of course, be continually agitated to prevent sedimentation. In some installations it is found convenient to have two or three mixing tanks, each feeding one large storage tank. From the storage tank, the slurry is pumped to a small service tank in the mill, which supplies the machines by gravity. To prevent sedimentation, slurry from the service tank overflows continuously, the surplus being collected in a receiving tank, from which it is pumped back to the storage tank in the clay-house. The slurry is added to

the newsprint stock usually at the Trimbey or other form of proportioner. Alternatively it may be measured in boxes of suitable capacity, and added to the beaters.

Alum, either in the form of kibbled 17 to 18 per cent quality, or as 14 to 15 per cent slab alum, is dissolved in tanks having a perforated false bottom fitted quite near the top. The alum is loaded on to the false bottom, and water



[*Bell and Robertson, Ltd., Aberdeen*

FIG. 110.—TYPICAL CLAY SLURRYING PLANT, SHOWING TWO MIXING TANKS FROM WHICH THE SLURRY FLOWS BY GRAVITY, THROUGH A DIRECT-DRIVEN ROTARY STRAINER, TO THE STORAGE TANK

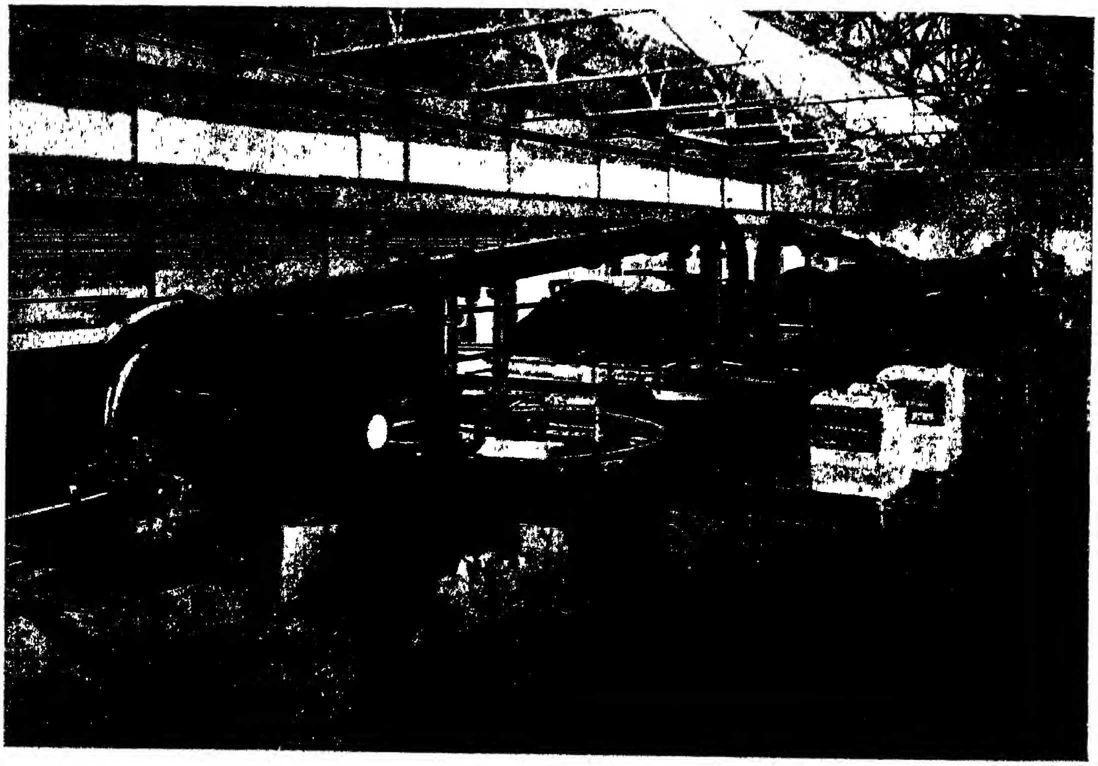
is run in until the solid alum is just covered. As the alum dissolves, the denser solution falls to the bottom of the tank, thus giving some natural circulation which helps to speed up the dissolving process. Sufficient alum is added to the tank to give a solution containing 2 to 5 lb. per gallon. A useful check of the concentration can be had by testing the solution with a Twaddell hydrometer.

From the mixing tank, alum flows by gravity to the storage tank, from which pipe lines take it to the machines. The feed may be arranged discontinuously at the breakers or beaters, or continuously at the proportioner,

In some mills it has been possible to dispense with alum altogether, since it is now recognised that size is not required in newsprint. In general, however, troubles such as sticky presses are likely to arise if the stock is not kept down to a pH value of about 5.

Alum solution is a very corrosive liquid and must be handled in lead-lined or other suitably protected tanks and pipe lines.

The dyes used for newsprint are almost exclusively basic dyes because they are cheap, they are bright colours, they dye directly without difficulty and the fact



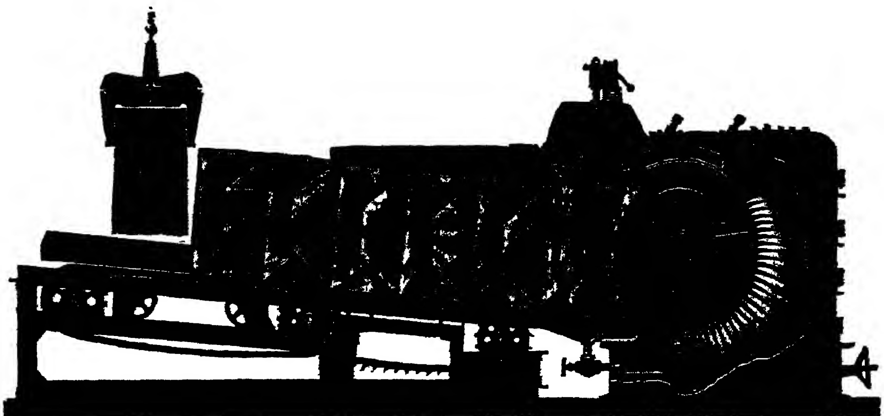
[*Walmsleys (Bury), Ltd.*

FIG. 111.—BREAKER AND BEATER FLOOR FOR THE PREPARATION OF STOCK FOR TWO MODERN NEWSPRINT MACHINES

that they are fugitive is of no consequence. In modern mills they are dissolved in bulk, and added to the stock at the proportioner. This is a clean and convenient method of dyeing, as the beater floor is kept completely free from dyes, and shades can be more quickly and easily controlled the nearer they are added to the machine itself.

Preparation and Properties of Stock.—The preparation treatment of baled pulp for making newsprint stock consists essentially in breaking up the laps and then disintegrating the fibres so that they are finally all separated from one another in a uniform suspension ready to flow on to the wire of the paper machine. There is little if any beating required.

The method of breaking that is still the most popular is to use the common type of breaker having a roll fitted with bars that are saw- or wavy-edged. The bars are usually equally spaced round the roll about 18 inches apart, and there is no bed-plate. The roll operates in a fixed position about 6 inches above the bottom of the breaker trough, and it is not adjustable or counterbalanced like a beater roll. Breakers of this type for newsprint stock are built to hold about 1 ton (air-dry weight) of pulp at a consistency of 5 to 6 per cent, the capacity of the trough being about 4500 gallons. Bales are fed by hand, a few laps at a time, into the breakers just in front of the roll, the filling operation taking altogether about 10 minutes. After a total period of 20 or 30 minutes, including filling in, the stock is sufficiently broken up to be dropped to the breaker chest.



[*Sturtevant Mill Co., Boston, Mass.*

FIG. 112.—STURTEVANT BALE PULPER

Accepted stock has to pass through the semicircular perforated screen plate

Although this method of breaking appears, on the face of it, crude and unscientific, and represents no advance, other than in the capacity of the breaker, over methods that have been in use for very many years, it compares surprisingly well in labour and power costs, and in capital expenditure, with proposals made from time to time with a view to modernising the procedure and reducing the amount of man-handling required.

Among these proposals may be mentioned the Sturtevant pulper, which is illustrated in Fig. 112. With this equipment, bales are mounted on a conveyor which carries them continuously to a revolving drum fitted with claws that tear at the surface of the pulp and effectively break it up. A shower of backwater plays on the surface where disintegration takes place, and the resulting slush falls below into a breaker chest.

Another system, known as the Liebeck fibrator, is an attractive alternative to the generally adopted breaker method. In this arrangement, bales are packed together in line on a conveyor, but instead of being forced by the moving conveyor direct against a disintegrating roll, the pulp falls, bale by bale, into a large oblong concrete breaker chest capable of holding 5000 lb. of stock at 3 per cent consistency. The chest is fitted with a horizontal shaft, on which are fitted large disintegrating propellers, and as the bales are fed in, they fall some 10 or 12 feet either on to the shaft itself, or on to stationary horizontal concrete baffles which protect the propellers. This heavy fall helps to split the bales into laps, and then the propellers thrashing round are very effective in breaking the laps down to slush form. These breakers require about 30 minutes, including loading time, to treat the stock.

Both the Sturtevant whole bale pulper and the Liebeck system are able to handle pulp that is difficult to disintegrate rather more satisfactorily than conventional breakers. Thus, the Liebeck breaker is able to handle frozen pulp without any prior hacking and man-handling of the bales to separate the laps. The Sturtevant pulper has been employed successfully to break up dry Kraft, a task which is very difficult in an ordinary breaker. Both these methods of pulping, however, suffer from the disadvantage that labour is still required to load the pulp on to the conveyors, and to remove the baling wires. Perhaps for this, among other reasons, these newer methods have not displaced the breaker system to any appreciable extent for newsprint.

An arrangement for the breaking and preliminary treatment of pulp that has operated satisfactorily in several news mills in this country has been to have for each machine, making about 150 tons of paper per 24 hours, a battery of three 1-ton breakers for handling the groundwood, one 1-ton sulphite breaker and two 1-ton sulphite beaters. The beaters, unlike the breakers, are fitted with bed-plates, but they do very little real beating, and chiefly help to disintegrate the pulp further. The groundwood breakers operate independently and discharge the stock into a common breaker chest. The sulphite breaker may be arranged to discharge the stock direct to a pump which transfers the stock to one of the two beaters, where the pulping treatment is continued for about an hour. The sulphite beaters then discharge the stock into a sulphite stock storage chest.

Groundwood and sulphite pulp are thus, in modern practice, broken and disintegrated separately in the early stages. The breakers, in each case, are fed with back-water obtained by gravity from the back-water storage tank, and when the broken-up stock is let down into the storage chests, additional back-water is added to wash down the rather thick 5 to 6 per cent stock. This washing dilutes the stock to about 3 per cent, and in order to keep the

concentration as constant as possible, the chests are allowed to fall always to the same level before the next breaker-full is dropped. The addition of dilution water is continued via the breaker until the stock-chest level has been brought up to a predetermined level to give the required concentration of 3 per cent.

Storage chests for both sulphite and groundwood stock are usually rather long and narrow, the width being roughly the same as the height (see Fig. 106). They are fitted with a horizontal shaft to which are attached paddles, or propellers, to provide the necessary agitation to prevent sedimentation or flotation, and to help in some small way in the soaking and disintegrating process. For the sake of cleanliness, the tanks are permanently closed in with a manhole at the top through which access can be had for inspection and repair purposes. The capacity of these chests is usually sufficient, together with the refiner and machine chests, to give about 4 hours' supply of stock to the machine. The greater the capacity the better the opportunity there is to get the stock thoroughly mixed, which helps to maintain a uniform consistency. It also gives some margin in the event of any breakdown occurring in the breakers. On the other hand, a large chest-capacity makes it difficult to make any rapid changes of furnish, if this should be necessary.

The stock from the breaker and beater storage chests may be refined separately, then mixed, by means of a proportioner, in the ratio needed to give the desired percentage of sulphite. After mixing, the stock, in most installations, is refined again, and is then ready to be fed to the mixing pump to provide the dilute stock for the breast box.

No hard-and-fast rules can be laid down as to the exact flow-system needed to give the best refining results. Normally two or three refiners, each taking about 250 horse-power, will be installed for a machine making 150 tons of paper a day. From the evidence available, it seems that two refiners should be enough for the work to be done.

The purpose of refining, so far as newsprint is concerned, is primarily to complete the disintegration of the stock, which, after breaker treatment only, is full of undisintegrated clots of pulp. Refiners are able to clear these away completely. Groundwood changes little in freeness, or other characteristics, on being refined, although sulphite pulp, especially if it is added to the breakers in an air-dry condition, may increase in strength considerably when refined. This increase does not, however, seem to be of primary importance, partly because the percentage of sulphite used nowadays is so low that its contribution to the strength of the finished sheet is rather small, and partly because the primary function of sulphite is to make full use of the long slender fibres to give wet strength to the immature sheet of newsprint, thus helping it to withstand the

stresses set up in passing from the couch to the drying cylinders. Refining helps to some small extent to control the wetness of the stock on the wire, but there is no doubt that groundwood is rather unresponsive to refiner treatment, and therefore it is more important that the right quality of groundwood should be obtained from the pulp mill, rather than that any attempt should be made to try to modify its quality by treatment in the paper mill.

The correct proportioning of sulphite and groundwood stocks is dependent upon the maintenance of a uniform consistency, and some reference has already been made both to the usefulness of large chests, and also to the importance of dropping breakers regularly and diluting the stock methodically in order to avoid excessive variation in consistency.

It may be found desirable, in addition, to control the stock automatically using one of the many types of consistency regulator available for the purpose. All these regulators depend, for their operation, on the stock changing in viscosity, as the consistency changes, and although this relationship is rather variable, depending, among other things, on the kind of pulp and the treatment it has received, a well-designed and carefully constructed regulator can give a very satisfactory measure of control.

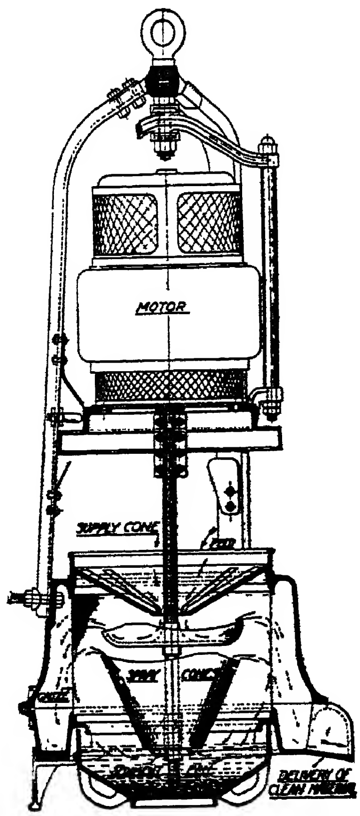
The separately prepared groundwood and chemical pulp stocks are mixed by means of a proportioner, of which a number of types and designs are available. These depend usually on the provision of a constant head of each kind of stock by pumping up to a receiver having an overflow for stock to return to the storage chest. From the constant head, or constant level compartment, the rate of flow of the stock is controlled by a revolving variable-speed paddle-wheel, as in the Trimbey proportioner, or by a rectangular weir having an adjustable width, as in the Tidbury proportioner. The two proportioned stocks are collected together in a receiver and conveyed by gravity to the mixed stock chest, from which the stuff is pumped for further refining and consistency control, finally being discharged into the machine chest ready for the mixing pump.

In modern mills, the proportioner is the place where, in addition to adjusting the ratio of groundwood to chemical pulp correctly, loading, dyes, and sometimes alum are added, in the form of a suspension or solution. As in the case of pulp, the rate of flow may be controlled by a constant head of the liquid, coupled with a feeding paddle rotating at the rate required to give the necessary dose. A more recent and very satisfactory method of obtaining a visual control of alum flow is to use a rotameter. This type of flow indicator consists of a very gradually tapering glass tube. A cone rises or falls in this glass tube, according to the quantity of liquid that has to escape between it and the glass tube; the greater the flow the higher the cone must rise to take advantage of the

taper to give the required larger clearance between the glass tube and the cone. Rotameters are obtainable already calibrated over the range of flow-rate desired.

From the proportioner, then, the stock is complete with colour, loading and alum, and after further refining it is ready for the machine.

In dealing with the correct furnishing and preparation of the stock for making newsprint, stress must be laid on the importance of selecting pulps which are suitable for the purpose, and on the need for keeping out of the system foreign material likely to affect adversely the quality of the sheet, or cause breaks on the paper machine. Methods of evaluating pulp quality have advanced very considerably during the past few years, and in modern newsprint mills the testing of the quality of shipments is an important part of laboratory control work. The tests made include freeness determinations, the estimation of shive content and the preparation and examination of laboratory sheets. Detailed information about methods of this kind is available in the technical literature and in the reports of committees which have made a special study of the subject.



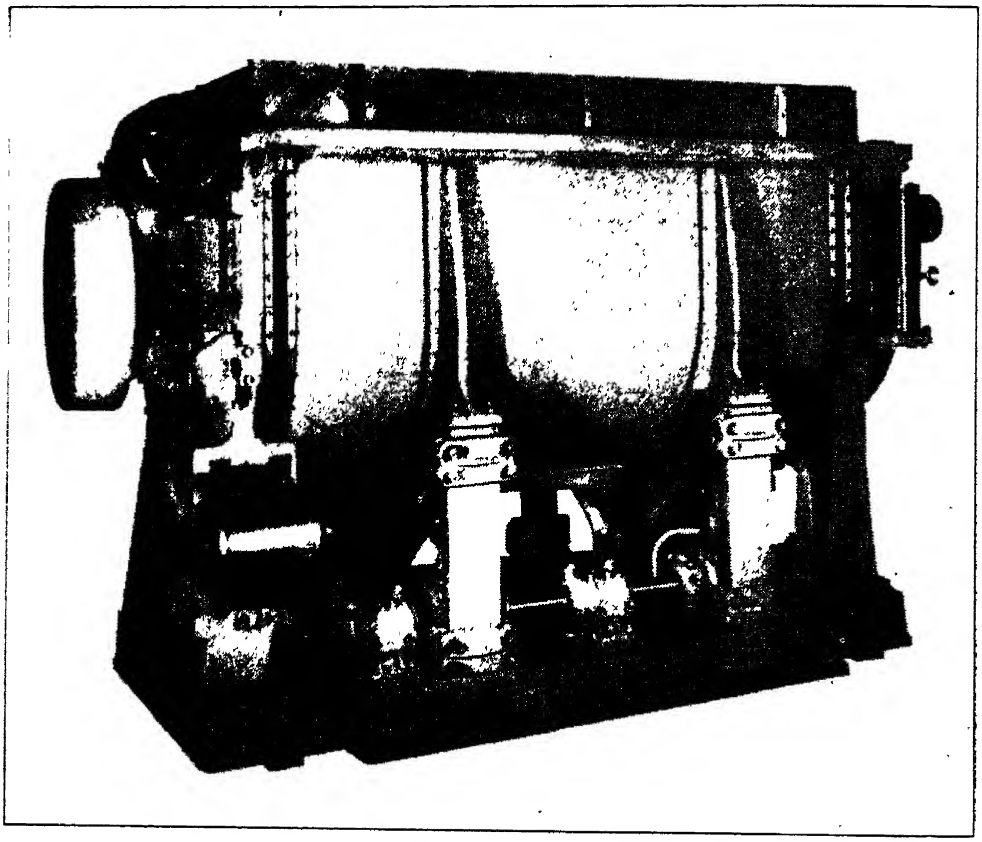
[*The Watford Engineering Works, Ltd.*

FIG. 113.—THE ROTOSPRAY FOR CLEANING CLAY AND OTHER LOADINGS AND COLOURS. THIS ALSO HAS A HOMOGENISER FOR SEPARATING THE PARTICLES AND GIVING AN EVEN FLOW OF CLEAN SLURRY

The precautions taken to prevent foreign matter getting into the paper consist firstly in keeping a careful control of the cleanliness and general condition of all pulp used; this is usually done when the pulp is first received at the mill and is tested for moisture content. Secondly, coarse grids are fitted at various points in the pipe lines, in boxes which may be isolated and cleaned out periodically without interrupting production. The final point for holding back unwanted material is at the strainers through which the stock passes immediately before flowing to the breast box.

Strainers and Slice.—The finally prepared stock, regulated to a uniform consistency of 2½ to 3 per cent, and containing dyes, alum, and loading, is pumped to a head box, from which the required quantity of stock flows through the stuff valve to be mixed at the mixing pump with the back-water recovered from the wire pit. It is important to have a constant pressure of stock behind the stuff valve, as this is the valve that is used for

controlling the basis weight of the paper being made. The valve itself should preferably be specially designed so that a large number of turns are required to change the setting from the shut to the full-open position. This will give greater delicacy of control, and therefore more accurate basis weight adjustment, than can be obtained from a valve that requires only a few turns to



[*Vickerys, Ltd., and Walmsleys (Bury), Ltd.*

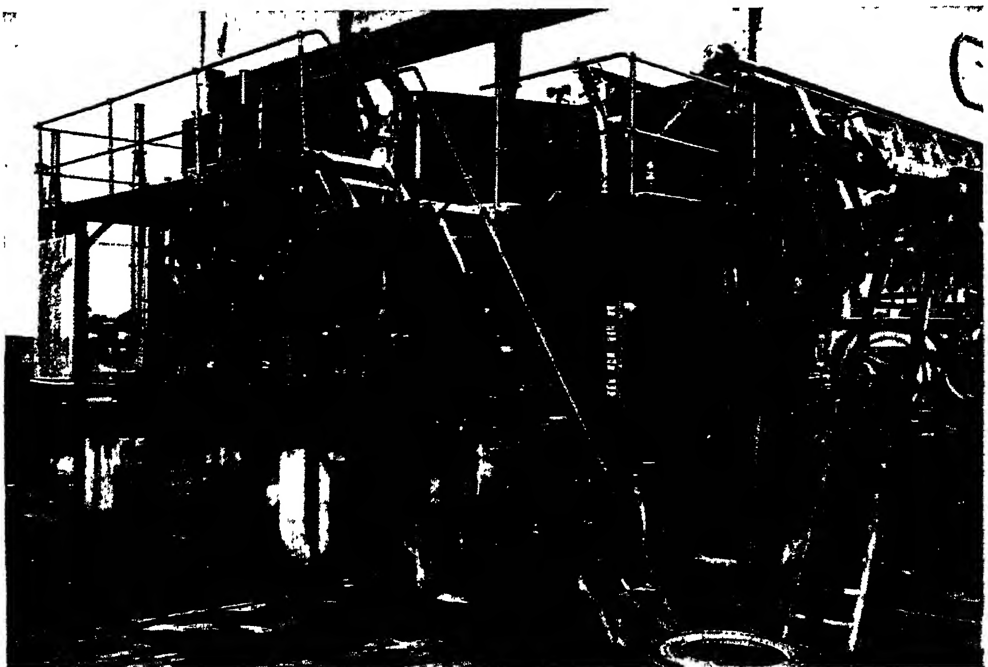
FIG. 114.—LATEST TYPE OF HIGH-CAPACITY BIRD SCREEN FOR NEWSPRINT STOCK

The lower motor operates the shake motion and the upper motor drives the gearing which keeps the cylindrical screen turning slowly round

produce a large change in the rate of flow. The diluted stock from the mixing pump passes direct to the strainers which, usually, are located behind the breast box.

The strainers needed for news stock must, of course, be of large capacity. The type used (see Fig. 49) is that known as the inward-flow strainer, because the stock is pumped to an outer container and flows by gravity through the slits of the screen to the centre. The screen itself is a large cylinder in which thousands of slits, parallel with one another and in rows, are cut. The usual width of slit for news is about 0.0025 inch. In operation the stock is helped

through these narrow slits by the jogging motion of the outer half-cylindrical container, which is flexibly coupled to the main framework of the strainer by rubber jointing each end. Material, such as coarse shives and slivers, which is rejected by the screens, will accumulate in the outer jogging container. It may be removed by bleeding continually a small quantity of stock from the bottom of the container and passing it to an auxiliary flat screen, such as that



[*Walmsleys (Bury), Ltd.*

FIG. 115.—A TYPICAL STRAINER, BREAST BOX AND PROJECTION SLICE ASSEMBLY FOR A LARGE NEWSPRINT MACHINE

On the left, the flexibly mounted container of one of the four inward-flow cylindrical screens can be seen

illustrated in Fig. 50, where accepted stock is returned to the wire pit, and rejected material is sent to the main drain.

A large machine producing 150 tons of newsprint a day will require four strainer units mounted parallel to each other and parallel to the direction of the machine. The screened stock is discharged from the strainers into the flow box which leads it over various baffles and weirs to the slice (see Fig. 115). In the single case of the world's largest paper machine, making 200 tons or more of paper per 24 hours, there are six strainers all arranged at right angles to the direction of flow, in two lines of three, on either side of a central collecting trough.

The art in designing efficient flow (or breast) boxes consists firstly in aiming

at keeping the stock as uniformly dispersed as possible; secondly, in preventing, as far as possible, eddy or other local disturbances from arising, and lastly, the stock must be projected on to the wire at a speed which gives the most desirable sheet formation and sheet properties generally. The optimum speed of projection is of course intimately bound up with the wire speed. Normally it is found that the best practice is for the stock to be projected at a rate which is 5 to 10 per cent slower than the speed of the wire. Flow boxes must, of

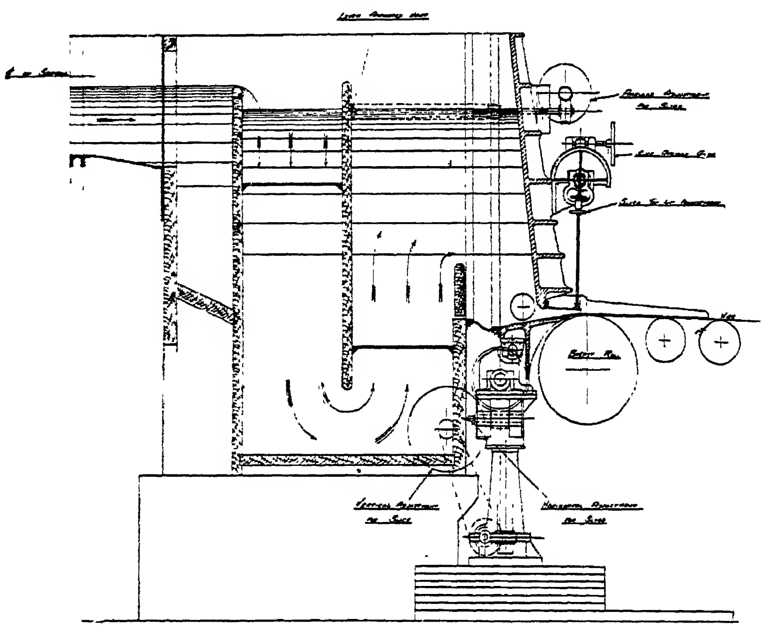


FIG. 116.—SECTION THROUGH A TYPICAL FLOW BOX AND SLICE FOR A HIGH-SPEED NEWS MACHINE

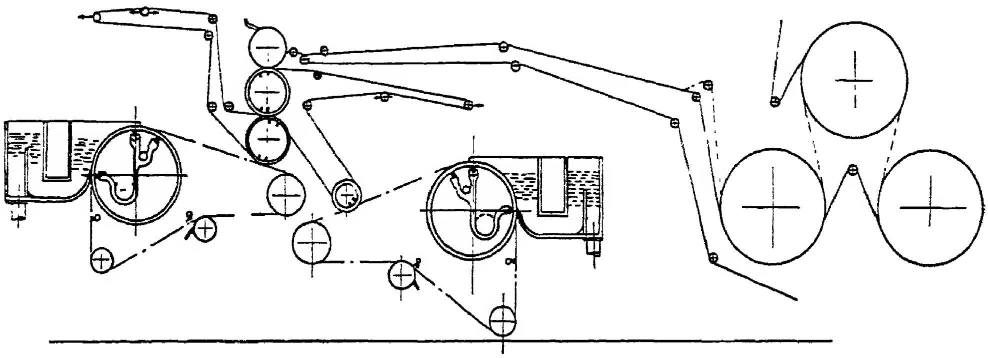
course, have no dead spots where slime and dirt can accumulate; a clean design, in this respect, is consistent with the need for producing a uniform rate of stock-flow to the slice.

The so-called projection slices (see Fig. 115) are used almost without exception in high-speed news machines, although there are one or two other kinds of slice working on different principles, and these may one day modify newsprint slice technique. There is, for instance, the Millspaugh arrangement, in which the stock contacts directly with a suction-operated forming cylinder. This arrangement, incidentally, has the advantage of dispensing with the conventional wire part of a paper machine. Another interesting development is the pressure slice in use in one or two mills in the U.S.A. In this arrangement the wire itself forms the base of a kind of swan-necked breast box. The stock impinges on the wire and is to some extent forced down against it, giving an immediate initial mat of fibres on the wire. The quantity of stock available for build-

ing up the remainder of the sheet thickness is governed by the height of the projecting slice 'lip' above the wire. This slice is being found especially useful for very free stock.

The Wire Part.—The wire part of a news machine is different from that of slower-running machines in that there is usually no shake fitted, the section is removable as a whole to facilitate wire changing, and it has fewer table, or tube, rolls.

When the stock flows on to the machine wire, drainage of the water commences right away, but only a small proportion is removed by the effect of gravity alone. Most of the water which is removed before the suction boxes



[*Millspaugh, Ltd., Sheffield*

FIG. 117.—ARRANGEMENT OF MILLSPAUGH DUPLEX VACUUM-FORMING MACHINE WITH STACKED SUCTION PRESS

This machine has no slice, the wires are very short, and the duplex sheet is made by combining the under sides of the two webs, thus giving finished paper having two top sides

are reached is withdrawn by the effect of the contact of the table rolls with the underside of the wire, and by the suction produced as they revolve rapidly round. This can be seen by observing what is happening under the wire, and also to some extent the action is indicated by the appearance of the stock on top of the wire.

The very large volume of water handled at the wet end of a news machine makes it necessary for the table rolls to be rather large in diameter. On a 220-inch machine the diameter would be 11 or 12 inches, while on a 300-inch machine the diameter is 15 inches. This large size is also needed to prevent whip at the high speeds at which the table rolls rotate.

Some of the water drained from the stock tends to be flung back on the underside of the wire by the centrifugal action of the rolls. This can spoil the formation of the sheet, and in order to prevent the trouble the practice is very often adopted of fitting baffles between the rolls, especially near the breast roll. Alternatively it is helpful to space the rolls fairly far apart.

The wires used for making newsprint are almost invariably about 60 meshes per inch in the cross direction and 40 in the machine direction, and the recently developed long crimp or twill wires (see p. 166) are used very extensively for news.

Drainage on the wire increases the consistency of stock from about 0.8 to about 3 per cent, at which point the suction boxes or flat boxes, as they are sometimes called, come into action, raising the consistency to around 16 per cent. Finally the remaining water, which is capable of being removed while the sheet is still in contact with the wire, is taken out by the couch where the concentration is increased to about 20 per cent.

The finally diluted stock fed to the flow box of a newsprint machine is very heterogeneous. The freeness will be about 50 c.c. Canadian standard, and the china clay will account for about a quarter of the 0.8 per cent of total solids, if an average ash content of about 8 per cent is desired in the sheet being made. The quantity of very fine fibre and clay present in flow-box stock is very much higher than it is in the thick stock delivered to the mixing pump. This stock will have a Canadian freeness figure of about 125 c.c., and the total solids will have a china-clay content of about 10 per cent.

The reason for the change in the composition and properties of the stock when it gets to the flow box is that an amazingly large proportion of the stock that flows on to the wire passes through the meshes by drainage and by the action of the table rolls. Flow-box stock having a consistency of 0.8 per cent will give rise to an average consistency in the wire pit of about 0.3 per cent. This means that nearly 40 per cent goes through the wire. Most of this fine short-fibred stock goes back again to the mixing pump to be delivered once more to the flow box. It therefore does not represent lost material, but its circulation back into the flow box is the reason why the stock issuing from the slice is so very different in properties and composition from the thick stock fed to the mixing pump.

The number of suction boxes fitted to the wire will usually be about eight, and the suction will be graded from about 5 inches of mercury to about 10 or 12 inches. The tops of the boxes must be fitted with some material that will give rise to as little friction as possible between the rapidly travelling wire and the suction boxes. Many different materials, including glass, granite and synthetic resins, have been tried, but by far the most popular is still wood. A hard wood, such as maple, arranged so that the grain is perpendicular to the wire, gives very satisfactory results, both because it requires attention less frequently than horizontal-grain suction boxes, and also because the load on the couch motor is reduced to a minimum (see also p. 183).

A dandy roll is usually run, even on the fastest news machines in the country. It closes the sheet and gives a more uniform look-through. Incidentally, a dandy roll enables an identifying water-mark to be applied.

The couch on a modern news machine is essentially of the suction type (see Fig. 69 and p. 192), otherwise economical speeds cannot be attained. Occasionally a light rubber-covered top couch roll is used as well, but opinion is divided as to whether this is really helpful. The vacuum at the couch is usually about 17 inches of mercury.

The Press Part.—During recent years quite a number of proposals have been made with a view to improving the pressing of newsprint.

Some years ago it was quite common practice to have two plain presses followed by a reversing third press, all with felts. Nowadays the first two presses are almost invariably suction presses; the third press, in the development of modern practice, was first deprived of its felt, then, by putting the brass roll at the bottom and the granite roll on top, it became a straight-through smoothing press. Finally, tests showed that it had very little, if any, effect at all on the finish of the sheet, so that, in present-day installations, there is usually no third press at all.

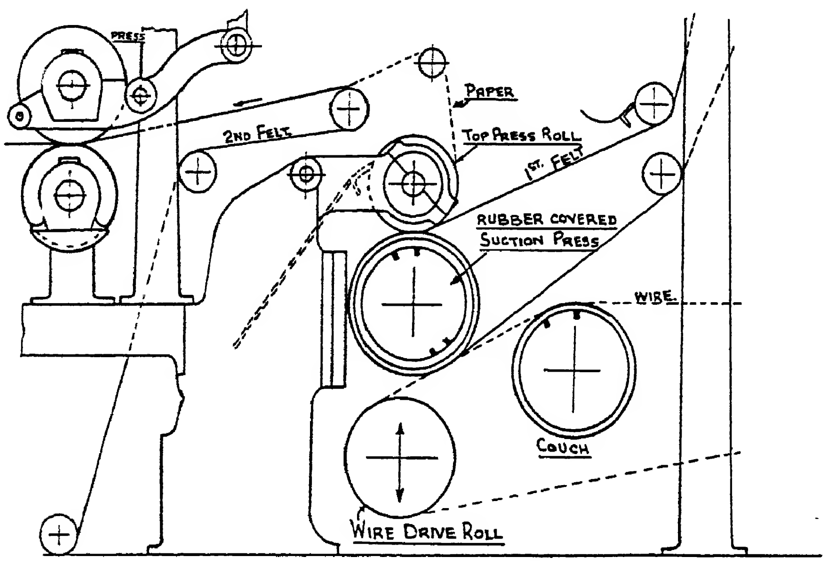
The bottom rolls of both first and second presses may be rubber-covered or just plain brass. Rubber-covered rolls have the advantage that they widen the contact at the nip, thus giving less drastic treatment to the paper. The rubber covering is also kinder to the felts, which are prevented from directly contacting the perforated brass roll. In some installations, notably on better-class paper machines, running at slower speeds than news machines, important increases in wet felt life have been obtained, but for newsprint made at high speeds, rubber-covered press rolls are not invariably chosen, because improvement in felt life has not in all cases been established, and also because the extra length of the drilled holes makes quite an appreciable difference to the capacity of the vacuum pump required.

Two other important developments in pressing, to which reference must be made, are the stacked press and the dual press. In the stacked press three rolls are arranged vertically above one another. The two bottom rolls are perforated suction rolls, each having a felt, and the top roll is granite. The sheet is transferred from the bottom roll to the middle roll by a suction box, and there is, in addition, a suction box at each of the two nips for removing water. Pressure is applied in the conventional way by lever systems.

In the dual press (see p. 196) there are again three rolls together, but in this case they are horizontal. The solid roll is in the centre, and the two perforated rolls are on each side. The dual press makes the arranging of the

felts and the disposal of the water, thrown out centrifugally by the rolls, rather more simple.

The stacked press and, more especially, the dual press are logical developments of the press part, the most important advantage of which is the saving in space. This is a specially helpful feature when old machines are to be modernised (see Fig. 75), but it is doubtful whether a newly planned newsprint machine would necessarily have a dual press installed in preference to two separate suction presses.



[*Millspaugh, Ltd., Sheffield*

FIG. 118.—DIAGRAM OF MILLSPAUGH AUTOMATIC COUCH WHICH ELIMINATES THE DRAW BETWEEN THE CONVENTIONAL COUCH AND FIRST PRESS

Other developments at the wet end of news machines have been concerned with handling the sheet in such a way that stretch is eliminated or greatly reduced at the draws. The stacked press and the dual press are themselves examples of this. The name of Millspaugh is especially connected with developments along these lines, and among his many interesting designs there is the automatic couch (Fig. 118), which picks the sheet off the wire by suction, thus eliminating altogether the draw from the couch to the press rolls.

Some indication of the importance of eliminating draws in this way may be obtained from the following figures, which have been carefully measured at different points on a modern news machine fitted with a suction couch and two separate suction presses:

	Speed f.p.m.	*Speed Increase f.p.m.*	*Stretch Per Cent*
Couch	1045	—	—
First press	1108	63	6.0
Second press	1120	12	1.1
First drying cylinder	1129	9	0.8
Sweat cylinder	1130	1	0.1
Pope reel drum	1130	0	0.0
Total wet end stretch	—	84	8.0
Total dry end stretch	—	1	0.1
Grand total for whole machine	—	85	8.1

The moisture removed by a modern press part is indicated by the following average figures:

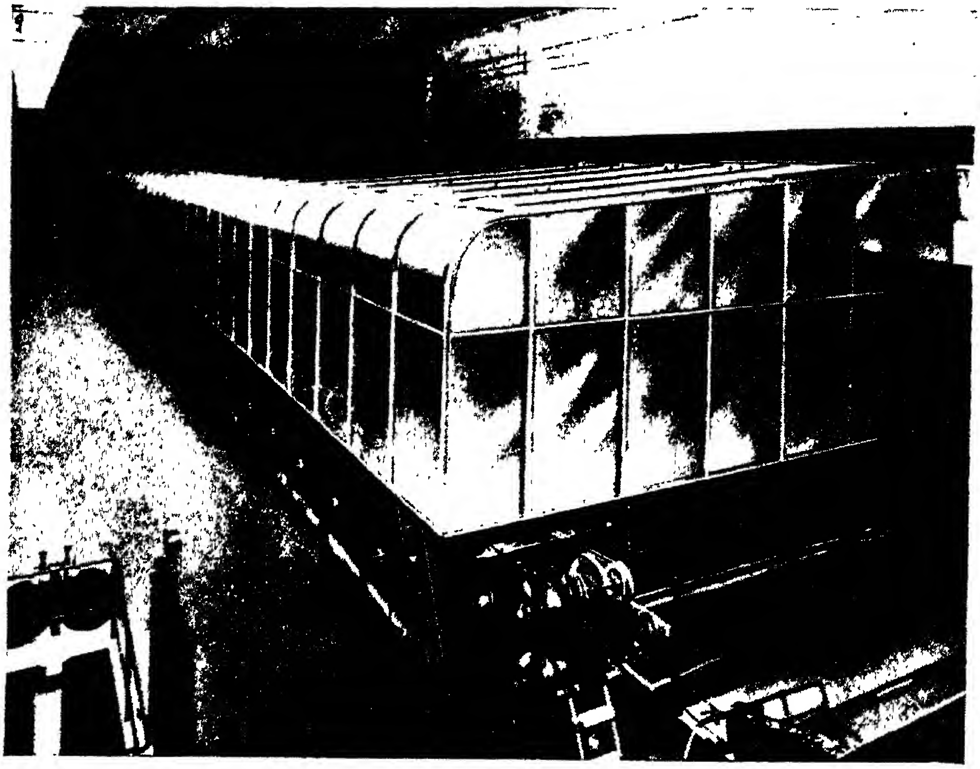
	Moisture Content Per Cent	*Vacuum Used Inches*
Couch	79	16
First press	68	17
Second press	66	22

Obviously it is important to remove as much moisture as possible by pressing, in order to reduce the amount of drying required to a minimum.

The Dryer Part.—The most difficult problem in the drying of newsprint is ventilation. The greater the width of a machine the greater is the difficulty of removing the moisture-laden air uniformly across the machine. It is the general practice to fit hoods by means of which the damp air is collected and discharged to atmosphere by a battery of usually six to eight fans situated above the back of the machine. Coupled with this system, hot air is blown in through trunking under the dryer section. The fundamental defect of methods of this kind, however, is that air cannot pass directly upwards past the drying cylinders because of the felts and the paper itself. Various methods have therefore been tried to promote adequate circulation between the cylinders, and the Grewin system is a typical example. In this system relatively small quantities of hot air are blown into the dryer section alternately from the front and back of the machine. The nozzles are placed as near to the paper as possible, so that fresh dry air may be brought continuously into contact with it.

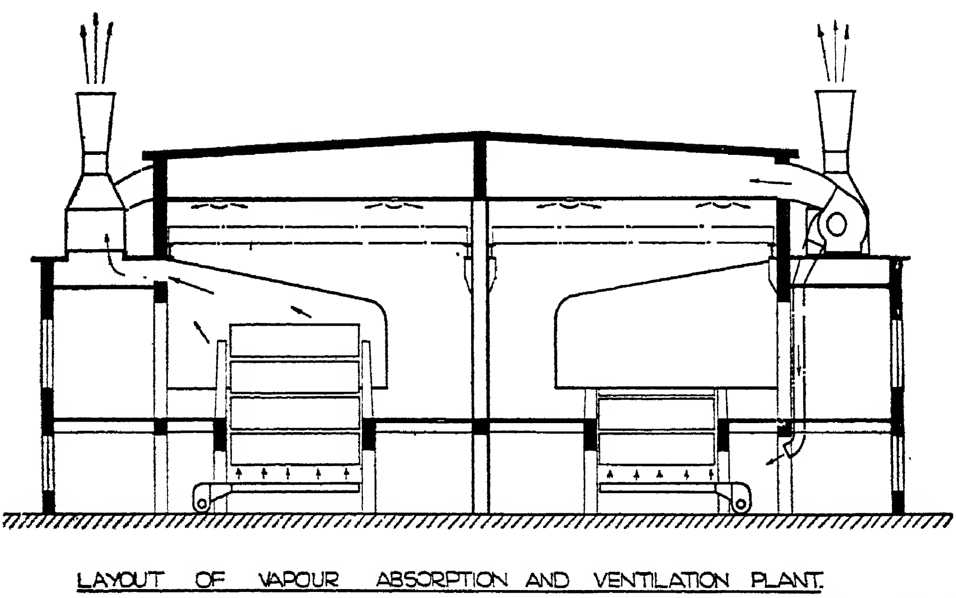
In spite, however, of all the attempts made to improve the uniformity of drying, it is all too frequently necessary to have to try to compensate for uneven evaporation by loading the presses or crowning them specially to give the lowest moisture content in that part of the sheet where the drying is least efficient.

In tackling drying problems on news machines the fundamental fact must



[Air Control Installations, Ltd., Ruislip

FIG. 119.—VIEW OF A NEATLY DESIGNED HOOD FITTED OVER THE DRYER PART OF A LARGE NEWSPRINT MACHINE



[Air Control Installations, Ltd., Ruislip.

FIG. 120.—DIAGRAM ILLUSTRATING THE CIRCULATION AND REMOVAL OF AIR IN THE DRYER PART OF A NEWS MACHINE

Note the arrangement by which air is admitted to the machine-house roof to prevent condensation

be kept in mind that practically all the moisture has to be removed by using air as a carrier. Water dissolves in air, and the higher the temperature of the air, the greater the quantity of water it can carry without becoming saturated. This mechanism of drying is entirely different from drying by ebullition, and it is doubtful whether any substantial proportion of the water removed from the sheet in a news machine is boiled off. Adequate supplies of hot air efficiently circulated and removed after becoming saturated, or nearly saturated, are therefore essential for satisfactory drying.

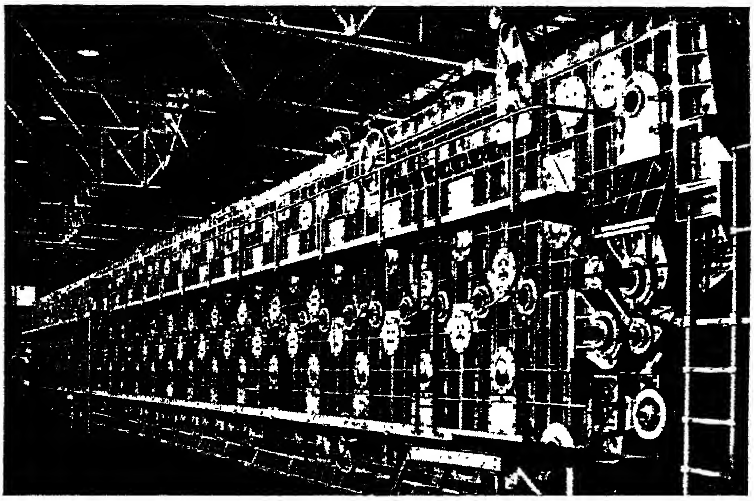
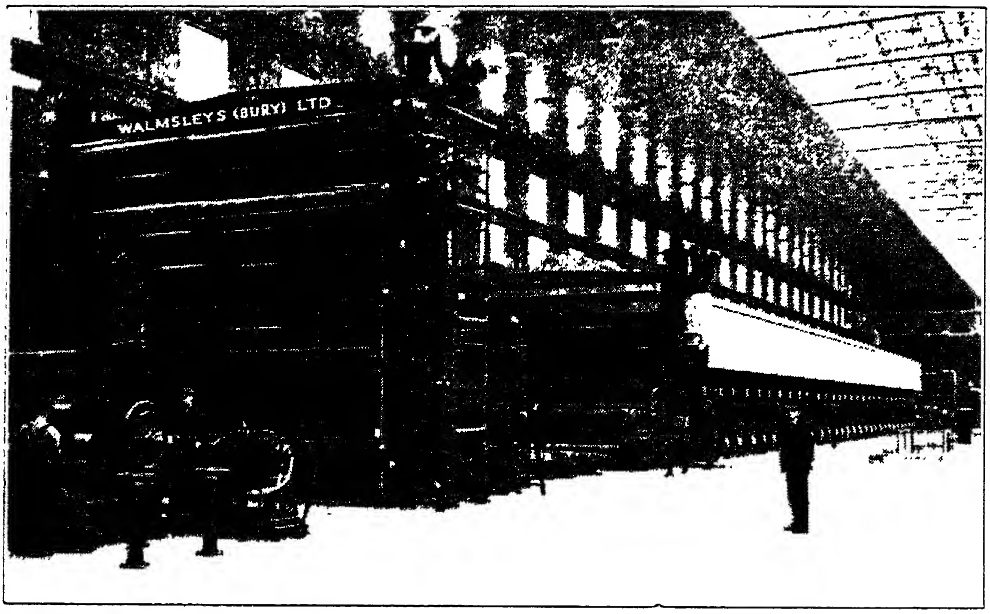


FIG. 121.—VIEW OF THE DRY END OF A FOURDRINIER MACHINE EQUIPPED WITH A MINTON VACUUM DRYER

News machines built to run at the high speeds prevalent to-day are usually equipped with about fifty, or in exceptional cases as many as sixty, 5-foot dryers. It is generally considered that felt dryers are not an advantage, although there is some difference of opinion on this matter. The last cylinder is usually arranged as a sweat cylinder for damping the underside of the sheet. This is especially important when making M.F. paper. Dry felts are used throughout the dryer section, with the exception that on some machines it has been found beneficial to omit the first bottom section felt, the idea being that free movement of air past the sheet, at this stage, is more important than pressing the paper hard against the cylinders by means of a felt.

The difficulties of arranging for uniform ventilation, and therefore uniform drying, in conventional dryer parts, were overcome a few years ago by the introduction of the Minton vacuum dryer. Although very few paper machines

have been fitted with this rather expensive system, the experiment was a very courageous one, and recently it has been applied successfully for pulp drying. In the Minton dryer all the cylinders are enclosed, so that they operate in a large air-tight compartment where the pressure can be reduced to about 73 inches of mercury. Working under these conditions, water can be boiled off, and thus no air circulation is required. Drying is therefore quite uniform provided the sheet is uniformly heated on the drying cylinders. Newsprint made on



[*Edward Lloyd, Ltd., and Walmsleys (Bury), Ltd.*

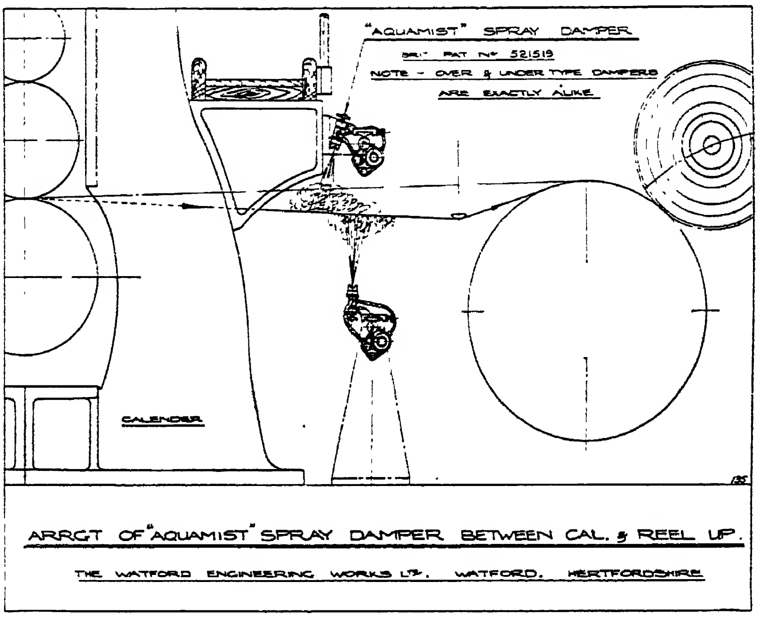
FIG. 122.—VIEW OF THE WORLD'S LARGEST PAPER MACHINE

machines fitted with Minton dryers is more bulky and absorbent than ordinary newsprint, and it takes the ink very well.

Finishing.—Newsprint made in this country has achieved a very high standard of quality, and one of the factors responsible for this is the super-calender. To obtain the best results from the super-calender the moisture content has to be carefully controlled. Because of the difficulty, already referred to, of drying paper really uniformly, it is necessary to over-dry slightly, and then to damp the paper to the desired moisture content to give the best results from the super-calender. It is difficult to give any very definite figures for moisture content, but normally, after drying and before damping, there should be about 6 to 8 per cent of moisture in the sheet, and the finished paper should contain at least 8 per cent of moisture.

The paper is damped on the machine just before reeling. A spray damper is used to moisten the top of the sheet, and the automatic reel change-over drum provides a ready means of applying moisture to the underside, the method being to spray the surface of the drum so that there is a film of water on it ready to be transferred to the paper.

Newsprint super-calenders are remarkable chiefly for their gigantic size coupled with the fact that the accuracy with which the rolls are ground is



[*The Watford Engineering Works, Ltd.*

FIG. 123.—DIAGRAM ILLUSTRATING AN ARRANGEMENT FOR DAMPING NEWSPRINT PRIOR TO SUPER-CALENDERING

In this arrangement, sprays of special design are used for both top and bottom damping

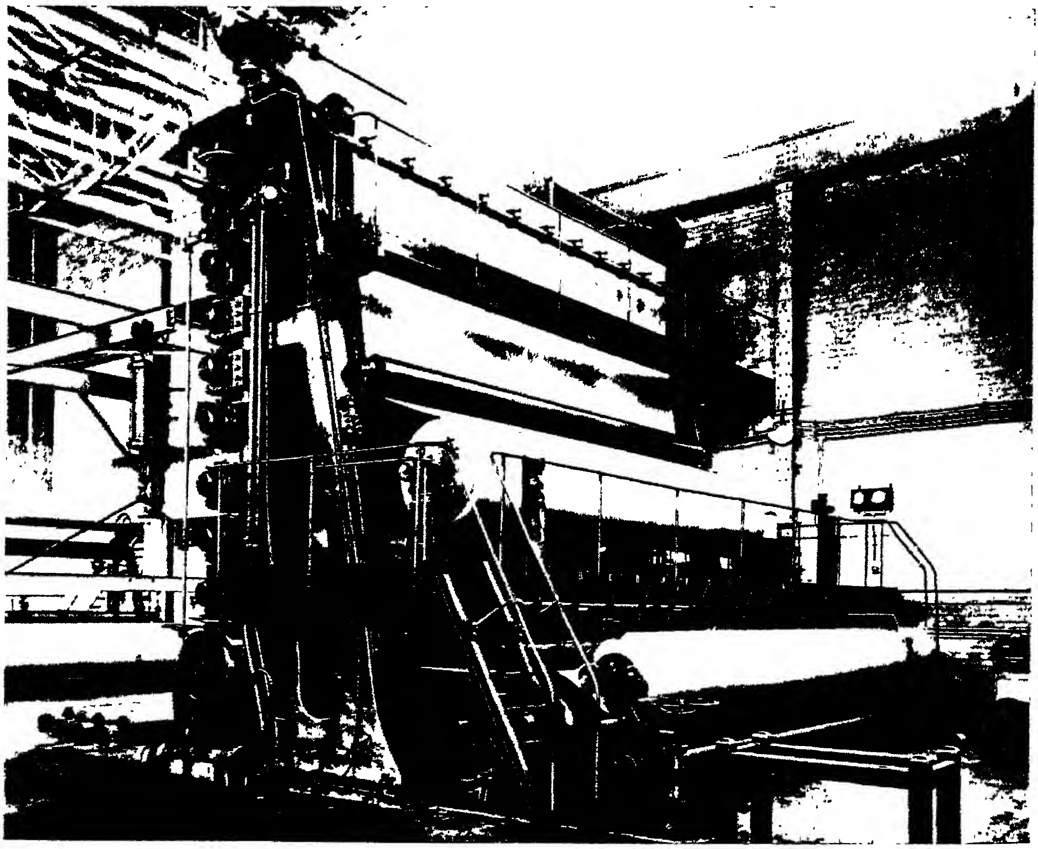
sufficient to enable a sheet some $\frac{3}{1000}$ inch thick to receive an amazingly uniform finish (see Chapter XX).

Future Trends of Newsprint Manufacture.—In this very brief review of some of the salient features of newsprint manufacture, some indication has already been given of the lines along which developments are occurring.

Undoubtedly one of the main trends in technical advance will be towards further increases in speed. The scientific staffs of some of the leading companies are already actively studying the conditions and problems that will arise at speeds of 2000 f.p.m.

Further efforts to cheapen the cost of production will be directed towards

decreasing, still more, the proportion of chemical pulp in the furnish. This effect will be materially aided by further studies of groundwood production with a view to producing qualities better suited to high-speed operation, and at the same time giving paper of adequate strength and good printing qualities. The processing of stock, in general, may in the future derive benefit from the



[*Edward Lloyd, Ltd., and Walmsleys (Bury), Ltd.*

FIG. 124.—THE WORLD'S LARGEST SUPER-CALENDER

The approximate total weight is 250 tons; the bottom roll alone, which is 36 inches in diameter by 26 feet (face), weighs 44 tons. There are ten rolls in the stack, five of them being wool-paper ones. The maximum specified speed is 2300 feet per minute

application of modern preparation plant, such, for example, as the Sutherland refiner, which is very economical in power consumption.

Finally, although this chapter has been concerned primarily with the newsprint industry in this country, some reference must be made to the recently announced commercial production of newsprint from Southern Pine. This is a project that has long been under consideration, but difficulties due to the

nature of the wood—particularly its high content of resins—have demanded many years of painstaking investigation to make the project a commercial possibility. The advantages of being able to use trees which grow to maturity in a dozen years or so have been a very attractive goal in developing this undertaking, and the new factory now in operation near Lufkin, Texas, may well be the forerunner of an important Southern newsprint industry.

HAND-MADE PAPER

THE making of paper by hand is unique in this respect, that it is still carried on in practically its primitive form, side by side with the most highly developed paper-making by machinery. When we look for the reason for this state of things, we find it in the very high quality and excellence of hand-made paper compared to machine-made for certain special papers, such as drawing and filter-papers, bank notes, and superlative qualities of writing and account-book papers, etc. This is shown by the many attempts made to give to machine-made papers the qualities or appearance of hand-made by cheaper methods.

Hand-made paper is generally made from the best grades of linen and cotton rags. Papers for very special purposes are made from new rags. The reason for this is that the process is very costly, and it would be poor policy to put low-grade stock through such a process.

The rags are treated in much the same way as for machine-made paper, but as the quantities to be dealt with are very much less, they can be allowed more careful sorting and more time for treatment than is the case where machines have to be kept supplied.

These high grades of rags require very light treatment in boiling and bleaching, and the resulting paper is, or should be, of very high quality and purity.

The boiling is usually carried out in open pans without pressure, very little lime or caustic soda being used, so that most of the original strength of the fibres is retained.

After boiling, the rags are picked over again to remove any 'contraries' such as black threads, buttons, etc., which may have become exposed during the process.

The rags are broken in, in breakers fitted with drum washers to carry off the dirty water, clean water being run in all the time until the water leaving the breaker is as clean as that entering it. The colour of the stuff is then improved by adding a little bleach, which is afterwards carefully washed out, until a starch iodide test shows no trace of chlorine in the stuff.

When we come to the beating, which is done in small hollanders with very light rolls, we find that longer and freer stuff, and also more highly fibrillated or wet stock, can be more successfully dealt with by hand than on the ordinary

Fourdrinier machine. For instance, for filter-paper, stuff that is so long, raw and free that it is impossible to get it through most strainers or to put it together on the machine wire can be made into a compact sheet by hand. And very highly fibrillated stock for strong ledgers, etc., can be made to heavier substances on the hand mould than could be run satisfactorily over the usual wet end of a Fourdrinier machine.

On leaving the beater the stuff passes to a stuff chest, whence it passes along sand traps over magnetic separators to remove metal and through strainers into the vat. As the quantity required by one vat is small, the straining of the stock is not forced, as it too often is for a machine, and this is a great advantage in producing clean paper. Being generally well fibrillated, the stuff is warm on leaving the beater, and it is warmed for ease and speed in making, and to save the vatman from having to slow down so as to handle cold stuff. It is also kept stirred while in the vat by an agitator or 'hog'.

Moulds for Hand-Made Paper.—The foundation of a mould for making hand-made paper is a framework of hardwood into which are set at convenient distances a number of thin transverse wooden bars, which are perforated with small sewing holes.

Used in conjunction with this frame is what is termed the deckle, which closely resembles a picture frame, and when placed in position on the mould provides the necessary edge to keep the pulp from running off the mould back into the vat. It also determines the exact size of the sheet of paper.

The surface of the mould (called 'the sheet') is provided with either a laid wire sheet or a woven wire cloth, the laid being the older form of covering. In either case it is sewn down to the framework, the sewing wire passing through the perforations in the bars.

The laid sheet is so called because its component wires are actually laid in position by hand as the cloth is formed, being held together by chain or twist wires, and the construction of this type of mould differs but slightly from the earliest types. At the present time most of these coverings are laid mechanically, with the result that the mould has a much more even surface, but there are still a good many moulds made with hand-laid 'sheets'.

In its earliest form a paper mould was probably formed by knitting or weaving vegetable fibres or split cane together to form a sheet, and then stretching this sheet over a mould in such a way as would provide an adequate surface for the pulp to be lifted from the vat and drained.

The introduction of drawn wire largely benefited the construction of paper moulds, both in the case of laid sheets, and later in the introduction of the woven type of sheet or cover.

It may be mentioned that the earlier types of moulds have the laid sheets

placed directly on to the bars, the position of the chain lines being directly over the wooden bars, and this causes the slight shading appearance in the paper around these parts.

With the mechanically-made 'sheet' it has become customary to introduce a laid under 'sheet' which, by giving a slight clearance between the top sheet and the mould, allows for a better waterway, gives a more evenly water-marked surface to the paper, and does away with the shaded appearance mentioned above.

Letters or devices are sewn on the surface of the wires or wire cloth. Some

[*J. Barcham Green and Son and the 'Daily Mirror' Newspapers*

FIG. 125.—HAND-MADE PAPER-MAKING

The vatman making a sheet of paper on the mould. The sheet is actually formed, and the 'deckle' is about to be removed

moulds have patterns or figures embossed on the wove wire cloth both up and down, so as to form thick or thin places in the sheet, and many beautiful designs are produced in this way.

The paper-maker who handles the mould and makes the waterleaf sheet is called the 'vatman' (Fig. 125). With the deckle in position he dips the mould into the stuff in the vat, and, lifting it up, he gives it the peculiar shake and movement which closes up the sheet and gives it the desired character; he sometimes causes a little wave to run over the mould, so getting rid of the surplus pulp, and leaving the fibres evenly felted behind it. He tips some of the water off the top and then places the mould on the bridge beside him, within reach of the coucher, at the same time removing the deckle.

The coucher tilts it into a sloping position to allow more of the surplus water to run through the sheet and off the under side of the wire cloth, and then presses it face downwards on to a felt. Skilfully lifting the mould from one edge first, he leaves the wet sheet on the felt, and places another felt on top of

[*J. Barcham Green and Son*

FIG. 126.—HAND-MADE PAPER-MAKING

Vat's crew at work on a two-sheet mould. The sheet is already formed and mould is ready for deckle to be removed, the upper end boy assisting, and in the foreground the layer picking up the felt with his right hand and the sheet with his left.

it. Another sheet is laid on the pile, and so on until a 'post' of alternate sheets and felts is built up.

This post is subjected to heavy pressure in a press, to squeeze out as much water as possible. The sheets are then stripped off the felts by a

'layer' and piled into 'packs', which are taken and pressed again for some hours. These packs are then separated sheet by sheet carefully, and then they are pressed again for twelve hours, when they are again parted, pressed again, and then hung up in a loft to be air-dried. In summer the natural air is enough, but in winter steam-pipes are used. When sufficiently dry the paper is stacked up in piles to mature and flatten out. This maturing process may take weeks or months. The waterleaf is now ready to be sized with gelatine.

The sizing is carried out in a sizing machine, which consists of a tub through which two endless felts travel slowly, with the sheets of waterleaf between them. After the sheets have been well soaked they are carried between squeezing rolls to force the size into the sheets and also to remove excess size from the surface of the sheets; this prevents subsequent discoloration by reason of patches of size lying on the surface.

After sizing, the sheets are stacked up in piles and covered with hot felt and allowed to stand for about twenty-four hours. This gives the size a chance to permeate the sheet thoroughly and the heat prevents the sheets sticking together. After this the sheets are parted by girls, so that warm air can get at them and dry off the surplus moisture.

The paper is afterwards allowed to stand in piles for a day and then again carefully parted sheet by sheet, care being taken not to strain the sheets unduly if they should be stuck together, otherwise they will be cockled and will never lie flat.

The sheets are again allowed to stand for a few hours, and are then taken to the drying lofts. These lofts are heated and care has to be taken to prevent cold air or draughts getting in, or the paper will be spoilt. Different temperatures are used for drying different qualities of paper. The paper may be dried flat on hessian screens, or hung over cow-hair ropes. Most papers are sized a second time after drying. The stronger the paper and the more fibrillated the stock, the more difficult it is to get the paper to take the size, owing to the absence of air spaces. After drying in the loft the paper is stacked in heaps to mature, and is then sorted over for defective sheets before being plate-glazed. It is then sorted over finally by experienced sorters, who separate it into good, retree and broken.

The most important features of hand-made paper are its great strength and its tendency to expand and contract equally in both directions after damping and redrying.

The shake given by the vatman is in two directions, so that there is very little difference in the tensile strength in the length and breadth of the sheet. Machine-made paper shows a decided difference in strength and expansion in the machine and cross directions.

The couching pressure is applied to hand-made paper slowly and directly at right angles, instead of the sudden rolling up of the machine couch rolls.

The expansion and contraction of hand-made paper, being much more even, are of great advantage for some special papers, such as bank notes and other papers which have intricate designs printed on them, and which must register correctly.

Water marking can be made very clear and distinct, and some very beautiful and elaborate designs are produced. While the dandy roll can only make an impression on the already formed sheet on the machine, the water mark on a hand-made sheet is moulded into the fabric. No loadings or resin size are used because, the paper being loft-dried, there would not be sufficient heat to fuse the resin in the sheet. Hairs from the felts were often left on the surface of hand-made sheets, causing annoyance when a pen was used. This trouble has, however, been eliminated recently to a great extent.

The substances of sheets are sometimes very irregular before the sorting, but they are on the whole astonishingly good, when the conditions of working are taken into account. The percentage of broken is naturally higher than that of machine-made paper.

Hand-made papers are mostly sent out in rough or low finishes, especially for drawing and painting, but those for writing are usually plate-glazed. Owing to the deep impression of the felt and the absence of the smoothing process between press rolls, it is difficult to obtain a close finish.

A steel pen-nib will generally be found more satisfactory than a fountain pen for writing on hand-made paper, the surface of which usually has a 'greasy' nature, because stationers think a rough paper *looks* better, and insist on the maker supplying this, when a higher glaze would make it write perfectly well, and it really looks just as good.

It is scarcely necessary to add that the vatman and coucher must be skilled and steady workmen, the vatman in particular, for he has to make sheet after sheet without deviating from the correct substance or altering his shake.

It is also quite a common occurrence for a vatman, owing to nervous strain, to lose control of the muscles of his arms, and, as it is called, 'lose his shake', sometimes only temporarily, usually permanently.

The vatman can only do his work properly if he is in good health and 'free from care'. The least mental strain or worry shows itself at once in the resulting paper, so that the substance, appearance and character of the paper are altered or irregular. Quite frequently, when beginning to make a certain paper after having just finished making a different size or substance, it will take some time before the vatman settles down and gets the paper right,

and he usually knows himself that it is wrong, and marks it with tabs so that it can be set aside for repulping or special sorting when finished.

The finished paper is finally sorted by 'layers', who are women of great experience. These layers throw out defective sheets, which are in their turn sorted again by 'second layers' into retree and broken, so that finally three grades are left—namely, good or perfect, retree and broken. These grades are all fit for sale, but the retree and broken are sold at a lower price, in the same way as machine-made papers. The reams are made up in various ways—viz.:

1. *Mill reams*, containing 472 sheets (432 good, with 20 broken sheets on top and the same number of broken sheets at the bottom of the ream); this method is now given up by most mills.
2. *Insides*, 480 sheets, all 'good'.
3. For export, 500 sheets, all 'good'.
4. *Retree insides.*
5. *Retree mill reams.*
6. *Broken.*

It is often said that hand-made papers are expensive. This idea is quite erroneous when the superlative excellence, strength and durability of the finished sheet are taken into account. Hand-made papers are actually cheaper than machine-made papers in comparison, when the conditions of manufacture are considered.

For instance, a mill with five vats, making about 3 tons of paper per week, requires 125 employees for the various processes, and burns 25 tons of coal, 60 per cent of which is for drying, some power being obtained from the river. It takes from *two to three months* for a sheet of paper to find its way through the mill, and the various processes entail about *one hundred* separate handlings.

There are a good many purposes for which hand-made papers are essential, and for some of these they are actually a good deal cheaper in the long run than are machine-made papers.

Drawings.—The fine texture and 'tooth' characteristic of hand-made papers render them essential for the beautiful work of the real artist.

Etchings.—For printing wet or dry, the etcher wants a paper which will withstand the pressure and yet be sympathetic to the plate, combined with a lasting quality and purity that are not to be found in machine-made papers.

Money paper and all documents which get a lot of handling have to be printed on the very best paper obtainable, and the slight extra cost of hand-made makes the paper much cheaper in the long run. Very intricate lettering and devices can be put into these papers, and the English hand-made mills make money paper for banks and Governments all over the world.

Mounts and Covers.—Half the battle, when one wants to display a good picture, is to have a suitable background, and there is nothing to equal a good hand-made mount, which can be obtained in white and almost any shade of colour, even to black.

Vellum Papers.—The amazingly strong imitation parchment papers made by hand are equal to and in some ways superior to real parchment. They are practically indestructible, and they are not so easily affected by heat, mildew, or insects as are skin parchments.

Filter-papers for the most delicate chemical analysis are almost invariably made by hand, and they are the most reliable, the amount of ash in some of the chemically treated 'ashless' papers being practically nil.

Notepapers and Envelopes.—There is something distinguished-looking and 'good' about hand-made notepaper which cannot be imitated by any of the machine-made varieties. A box of good hand-made paper is actually much cheaper than many of the gaudy cabinets and compendiums of inferior engine-sized notepapers which are to be seen in all stationers' shops, and which seem to have a ready sale.

Ledger Papers.—For ledgers and account books, which have to be durable and stand a lot of hard usage and fingering, there is nothing to equal the blue-laid English hand-made papers.

Printing Papers.—For costly editions of valuable books, and for *éditions de luxe*, hand-made printings are still in good demand, and they give an added charm to the volume when combined with good and tasteful printing.

A hand-made paper-maker is a craftsman who has served at least seven years of apprenticeship before he gets his 'Card of Freedom', and until he obtains this card, which may only be awarded him by the Society, he is not allowed to be employed in the making of hand-made paper. The result is that after many years of tuition there exists a body of workmen called 'The Original Society', who are highly trained and who enjoy a freedom not possessed by any other organization of workmen.

It is interesting in this connection to note that membership of the Society can be traced from generation to generation, son following father in unbroken succession, and several of the fifth generation are employed in the hand-made mills to-day. The same holds good of the employers also.

[We are indebted for much of the above information, and also for the blocks of the illustrations, to Messrs. J. Barcham Green, hand-made paper-makers, Hayle Mill, Maidstone.]

GELATINE-SIZING—HAND-SIZING—TUB-SIZING—AIR-DRYING

The best writing and typewriting papers, whether machine-made or hand-made, are always 'sized', or coated and impregnated with a solution of gelatine, in order that their surface may be more even and more resistant to ink.

Papers sized with a gelatine emulsion are freer from fluff and 'hairs' on the surface, as these are all glued down among the other fibres and do not become attached to the pen-nib. This glueing down does not, however, take place with the coucher hairs from the felts, as these are wool and not cellulose.

In the case of a gelatine-sized paper, the ink lies in the thin film of gelatine and dries there, so that it may, if necessary, be erased and other letters or figures substituted.

Papers are sometimes required to 'stand ink after erasure', which means that they must be hard 'engine-sized' before they are tub-sized. In this case, when the paper has been hard-sized in the beater, less gelatine is taken up in the same time, as it does not penetrate the sheet to such an extent, but lies on the surface. The writing is easily erased, the gelatine being removed with it, and more writing may be filled in without the ink 'running' to any great extent.

Gelatine-sized papers are much more durable, as the fibres are protected by the thin film from the oxidising agents of the atmosphere. They are also rendered more tough and will stand folding and rough handling. The gelatine also imparts other distinctive qualities to papers, such as 'snappiness', handle, feel and look-through.

Hand-Sizing.—All hand-made and, in some cases, machine-made papers are sized in sheets, and the method is called hand-sizing, as it was originally carried out by dipping sheets of waterleaf into a tub of gelatine.

The sizing is now done by placing the sheets between two endless travelling felts, which run through a bath of warm gelatine size. The sheets are carried into the size and thoroughly soaked in it, the felts, which are very thin, having holes punched in them to allow the free passage of the gelatine. The excess size is squeezed off by means of a pair of press rolls, through which the felts carry the sheets; the latter are then taken off and stacked ready to be taken to the drying loft, where they are dried by air at various temperatures. The

sheets may be hung by clips or laid on hessian, in which case they will be dried flat, or they may be hung over cow-hair ropes and dried with a 'back' or ridge down the centre, caused by the rope; such papers are called 'backed' and the ridge has to be cut out by means of a guillotine, the 'deckle edge' thus being absent on one side of each half of the original sheet.

Tub-Sizing.—In the 'tub-sizing' of machine-made papers in a continuous web the paper is run off a reel, or straight from the drying cylinders, through a tub of gelatine size and again reeled up to 'soak', or run straight over an air-dryer, which will be explained in detail in a subsequent paragraph.

Preparation of Gelatine Size.—Most mills do not now prepare their own size, but find it more economical and clean to buy the particular grade of gelatine which is best suited to their need, ready prepared in sheet form.

This method does away with the necessity of buying skins and wet pieces from tanyards, boiling them down and running off several 'draws' to make the sizing solution.

For those who wish to make their own size the following details may be of interest:

The wet hide pieces are soaked in cold water and washed in revolving drums to free them from the lime which has been used to preserve them.

The size is extracted from the skins by boiling them in copper-lined, jacketed heaters, into the bottom of which is fitted a wooden frame covered with openly woven cloth. The solution of size passes through this sieve and the slime and other objectionable matter are kept back.

The heat is brought up to about 170° F. and the charge stands for about 16 hours before being drawn off. The heat must be put on again before drawing off, in order that the first draw may run off easily to the store tanks.

The first 'draw' contains the strongest jelly, but one or two more 'draws' are made in order to extract the whole of the gelatine. The second heating, with a fresh supply of water, is conducted at a temperature of about 190° F., and is allowed to stand as in the first treatment.

A third and fourth infusion may be made, the third being heated up to about 200° F. and the fourth boiled for an hour or two.

The amount of water added to the heaters for each treatment must be regulated according to the strength of the size required, and will, of course, depend upon the quality of the skins. The size should be strained through flannel cloth over a wire sieve.

The strength of the size for the store tank is regulated according to requirements by mixing together various amounts of the different infusions, such as the first and fourth, second and third, or any other which may be found suitable.

For the reason that size of different strengths may be easily obtained in this way, some mills still continue to make their own. By using a bath of size made entirely or almost entirely from the first draw, a very hard-sized paper is obtained, and one the strength of which is very greatly increased; for other papers, weaker solutions will suffice.

A small percentage of white soap is added to the size and thoroughly mixed up before adding the alum; about 2½ per cent is the usual amount. If the soap is not put in before the alum the size will curdle. The soap must be pure tallow curd, and may be bought, specially made, under the name of 'paper-makers' soap'. The soap helps to give a high finish to the paper, and it also prevents the formation of glistening alum specks on the surface of the paper.

Alum is added in the proportion of about 14 or 16 lb. to 112 lb. of gelatine, reckoned on the dry weight. The function of the alum is threefold: it serves to stabilise the consistency of the sizing solution at various strengths and temperatures, and also acts as a preservative by arresting the formation and growth of destructive bacteria, which quickly destroy the gelatine and cause it to putrefy; the third function of the alum is to render the gelatine resistant to ink penetration.

The effect of the alum on gelatine solution is very curious. If it is slowly added, it causes the gelatine to thicken until it becomes almost solid; when, however, more alum is added, the gelatine becomes fluid again, and it is in this condition that it is used in the size-bath. About 12 or 14 per cent of alum will be required to produce this solution. The normal way of testing the density of the solution in the mill is by means of a special hydrometer which has two scales of figures.

For a good quality paper in substance about $16\frac{1}{2} \times 21$, 21 lb., 480's, the temperature of the bath should be 110° F., and the density 7, as shown on the hydrometer. This figure is arrived at by allowing for the temperature on the scale.

Only the best sulphate of alumina must be used, and it must contain no iron or free acid.

Excellent gelatine may now be obtained in the form of small sheets ready for dissolving, and this saves the paper-maker the lengthy and rather unpleasant business of preparing the size from skins.

These skin and bone glues are made in a wide variety of qualities and colour, from dark brown to almost colourless (bleached). In order to find a grade suitable for tub-sizing, various samples may be tested. The qualities most desired are penetration at high temperatures and good stiff gelatinisation at ordinary atmospheric temperatures.

This simply means that the solution should penetrate the surface of the

paper while it is passing through the tub, and then dry hard on the dryer afterwards, giving the maximum resistance to ink and moisture and the maximum increase in strength and bursting strain. When testing gelatines, the colour of the solution must be taken into account, because the use of dark-coloured solutions will bring down the colour of the paper to an appreciable extent.

A rough way of testing samples against each other is to weigh out pieces according to their price; soak in water for 24 hours, remove them and wipe off surplus moisture, and then dissolve in equal quantities of water in a water-bath. When all the jelly has dissolved, remove the dish from the water-bath and allow to stand until cold. The stiffest jelly will be the most economical, and, if its colour is satisfactory, will be the best for tub-sizing.

The stock solution of size is made in the following way: The sheets are placed in a tank, covered with cold water and allowed to stand for 24 hours. By this time they will have swollen to several times their original thickness, but they will not have dissolved. The water may be drained off and hot water added, or the temperature of the water in the tank may be raised to about 150° F. The jelly will dissolve, and soap may be added in the proportion of about 2 or 3 per cent on the dry weight of gelatine. When the soap has dissolved, 12 to 14 per cent of alum is added, and the size is now ready to be run to the store tanks. Here it is tested for strength, and if too strong it is diluted with hot water to the required strength. It is now ready for use.

The tub-sizing machine consists of a trough, either of wood, lined with lead or copper, or of cast iron with a copper lining. No iron- or steel-work must come in contact with the gelatine solution.

The trough is heated by a copper steam coil or may have a double bottom with hot water circulating across the under side, in order that the temperature of the size may be kept constant. The best method is undoubtedly that in which hot water circulates through the bottom of the entire tub, as in this way the whole of the solution is kept at a uniform temperature. The temperature of the size is indicated by a thermometer kept permanently in the tub. A thermostatic controller will give perfect results.

Various methods are used for leading the web of paper through the tub, and all paper-makers seem to have their own ideas about it. The main principles to be borne in mind, however, are that the paper should be soaked for a period sufficient to allow it to expand to the utmost, otherwise trouble will be experienced with ribbing or piping of the paper as it is wound up wet after leaving the tub. This ribbing is caused by the paper still taking in size and expanding while being tightly wound, and as it cannot expand easily outwards, it expands upwards and takes on a shape resembling that of corrugated iron.

A suitable arrangement of squeezing rolls must be fixed at the end of the

tub in order that the excess size may be removed from the surface of the paper before it passes to the air-dryer, or is wound up.

A satisfactory arrangement of tub-sizing plant is illustrated in Fig. 129, and a much more elaborate tub, with a steam jacket and other improvements, is shown in Fig. 127.

The paper is led, either direct from the steam-drying cylinders of the machine or from a reel, over a dancing roll and round a large wooden roll fixed in the front of the tub. This roll is half submerged in the size, and the web of paper passes under it and along the bottom of the tub to another large wooden roll, also half submerged in the size. The web is led round this roll, and out of the size, over a guide roll, and into the nip of the squeezing rolls.

The squeezing rolls are important, and various combinations are in use. They may be either brass on brass, rubber and brass, or granite and rubber, the latter making an excellent combination. These rolls, no matter of what they are made, must always be kept in good condition, free from ridges and blemishes of any kind, and they must fit evenly the whole way across, otherwise damp patches will occur in the paper, and these will show in the finished sheet. Rubber rolls must be most carefully handled, as they are easily scratched and damaged, and the least mark in the roll will leave a corresponding mark on the paper, which may be visible only in certain lights.

The rolls must always be kept clean, and the top roll should be provided with a doctor and spray of water in order to wash off any froth or scum.

The top roll should be fitted with levers and weights, so that the pressure may be regulated.

Mention has already been made of the thermometer which is fitted in the tub; this should be in such a position that it may be easily seen all the time, as endless trouble may be caused by the temperature falling below its proper height.

During the working of the tub a great deal of froth is formed by the agitation of the size; this must be removed regularly in order to prevent it becoming hard and getting on to the web, and being pressed in by the squeezing rolls, thus causing hard size lumps or spots in the finished paper.

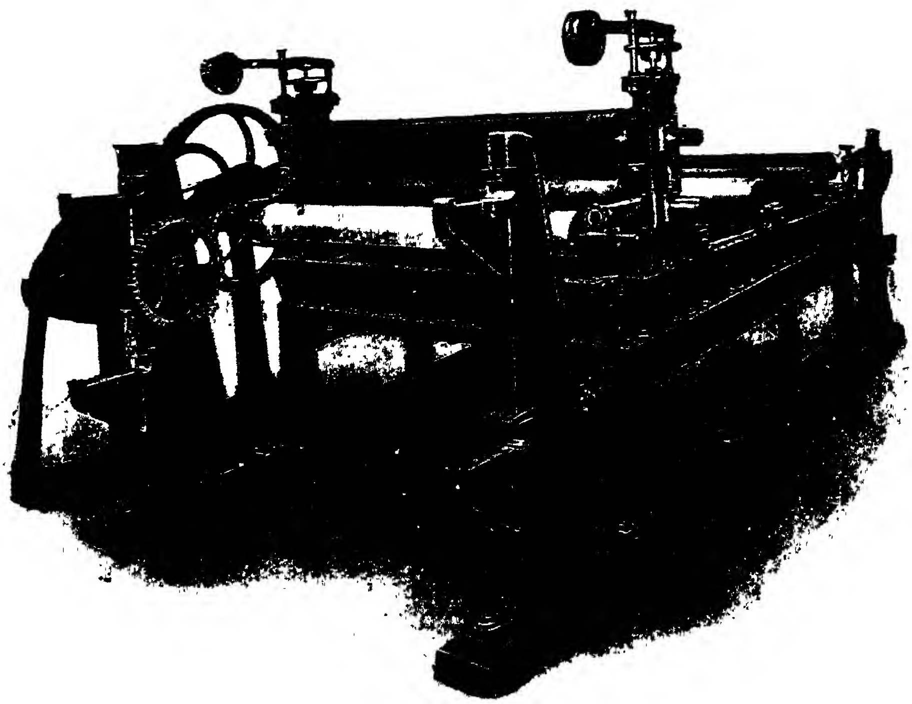
The level of the size in the tub should always be carefully regulated, as trouble is often caused by the level being allowed to get too low, and the scum which floats on top settling on the web, causing blemishes in the finished sheet.

The best sizing results are obtained when the paper enters the tub in air-dry condition and absolutely flat and free from cockles, creases and wrinkles of all kinds. It will be found advantageous to pass the paper over a scraper before it goes into the tub, in order to remove loose particles of rubber, which often

adhere to the surface and stand out prominently after passing over the drying cylinders.

Opinions differ as to whether the paper should be reeled up after sizing and allowed to stand and soak for a time before being dried. It is the practice in some mills to have several reels lying sized for some hours before drying, while others allow the reel to soak while the previous one is being dried; others, again, run the paper straight from the tub over the dryer.

So far as the efficiency of the sizing is concerned, there seems to be little to



[*Messrs. Masson, Scott and Co., Ltd.*

FIG. 127.—TUB-SIZING VAT AND SQUEEZE ROLLS

choose between the various methods, and our experience leads us to the conclusion that the latter method—namely, running the paper straight through the tub and over the dryer—is the most economical and convenient, although it means that the sizing and drying must always be done at the same speed.

Nevertheless, by this method we have sized papers in the same tub varying in substance from Large Post 7 lb. to Large Post 35 lb., with excellent results.

The second method seems a waste of time, as that part of the paper which has just left the tub is the first to pass over the dryer, and consequently one end of the paper will have been soaked for an hour or more while the other will be fresh from the tub.

The prolonged soaking of coloured papers is not advisable, as the colours are liable to fade.

Another drawback with reels which are allowed to stand and soak is the fact that the deckle edges often stick together and cause tears at the edges of the paper when being unwound at the dryer. To prevent this, the sides of the reel must be washed with hot water, or a jet of steam should blow gently against them during the unwinding.

The only point in favour of sizing and drying in two separate operations is that the speed in the 'straight-through' method cannot be varied to suit varying conditions of the atmosphere, and the slower the drying has to be done the longer the soaking of the paper in the tub.

When the two operations are separate, the dryer can be slowed or quickened at will, as the dryness of the paper demands, without interfering with the sizing.

Tub-Sizing with Feculose.—Feculose is sometimes used for tub-sizing writing papers, either in combination with resin or with gelatine size. Provided that the paper has not to be free from starch, excellent results may be obtained so far as hardness and resistance to ink are concerned, if resin is also used, and feculose is usually cheaper than the better grades of gelatine.

The method of preparing the solution is as follows:

200 lb. of feculose are stirred up with 90 gallons of water, warm but not above 160° F., and heated with steam injection until the temperature reaches 205° F. Allow to stand ½ hour to ensure thorough cooking, then add 800 lb. (80 gallons) of cold water.

10 lb. of resin size are placed in a tub and 8 gallons of water added, then heated to dissolve the resin size with the addition of ½ lb. of soda ash (the resin size is used just as it is delivered); then add 2 pailfuls of feculose solution.

10 lb. of alum are dissolved in 8 gallons of water with steam injection and 2 pailfuls of feculose solution are added.

The made-up resin size should now be added to the feculose solution through a sieve and mixed well with a wooden paddle; next add the alum solution and stir.

The feculose solution is now ready and should be about 5° to 6° Bé. (8° to 9° Tw.), but can be diluted to any desired strength.

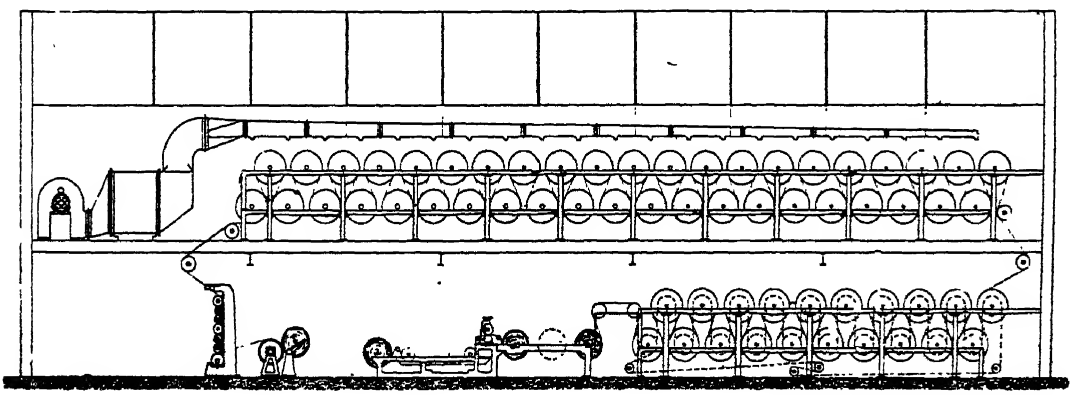
By following this method the colloidal condition of the resin is obtained, and therefore its maximum efficiency assured.

If the paper has been well sized in the beater, the resin and alum can be cut out, but it is advisable to add ½ to 1 per cent of formalin calculated on dry feculose to ensure the keeping qualities of the feculose solution. Where alum is used the formalin is not required, as the alum prevents fermentation. Formalin does not thicken feculose as it does glue.

With pure rag paper, where the resin does not exceed $\frac{1}{2}$ per cent, the quantity of resin added to the feculose solution should be doubled.

The sizing may be carried out in the ordinary size-tub of a tub-sizing machine and the paper then dried by hot air. As an alternative, however, a bath of feculose of about 10 per cent strength may be placed after the presses, and immediately before the steam-drying cylinders of the machine. In order to give full ink resistance, resin size is added to the feculose in the bath and precipitated in the usual way by alum. The heat of the drying cylinders does not affect the feculose size adversely, as is the case with gelatine.

Paper sized in this way should not be called 'tub-sized', as this term has long been applied to high-grade papers sized with gelatine, and it is likely to be misleading.



[*Messrs. Masson, Scott and Co.*

FIG. 128.—SECTION OF TUB-SIZING AND AIR-DRYING MACHINE, SHOWING HOT-AIR BLOWER ON TOP SECTION

The dried web is brought back to the bottom floor to be calendered

Air-Drying.—To carry out this operation the paper is led over a series of sparred drums about 3 feet in diameter by means of cotton tapes. The drums are composed of iron ends and spindle and have wooden spars. Some of them are also fitted with metal fans revolving in the opposite direction, in order to agitate the air and keep it in motion, and these fans also assist in keeping the paper flat and preventing it from running into creases. They are generally arranged in tiers.

Attempts have been made to dry a tub-sized paper in an enclosed dryer where hot air can be circulated, and thus dry the paper quickly and in a much smaller space than is required with the ordinary sparred drums in a heated room. So far as we are aware, however, up to the present this method has not been found very successful.

A typical air-dryer is illustrated in section in Fig. 128. If the paper has to

be dried at a high speed a very large number of drums is required, as many as 120 or even 140 being used on some machines.

The arrangement for supplying hot air consists of a series of steam-pipes running along the floor under the dryer, and the heat of the room is regulated by a valve worked in conjunction with a steam pressure gauge and a thermometer, or by a thermostat.

Some of the latest dryers also have a hot-air blower arranged to supply extra warm air to the upper tiers of the dryer, as it was found that by the time the air had risen from the first and second tiers it was so charged with moisture as to be unable to remove the final traces from the third tier.

There are several different forms of procedure adopted by various mills. In some cases the dryer is situated at the end of the machine immediately following the size-tub, so that the paper may be run straight from the drying cylinders, through the size-tub and on to the dryer, in a continuous web. This is the cheapest and best method, from the point of view of labour saving and the reduction of broke. Obviously if the whole operation of making, sizing and drying is carried out in one room, not more than five men and boys will be required, and when the machine has to stop to wash up or change, all five men will be available to assist at the wet end in cleaning sand traps, strainers, washing felts, etc., and so the length of time taken for this very necessary work can be reduced to about one-half of that which would be taken by a machine-man and one assistant, were the machine separate from the dryer.

Another advantage of this method is that a sized and finished sample of the paper can be got in the shortest possible time for the purpose of comparing it with the sample to be matched. The sizing always affects the colour of the paper in some degree, and if a waterleaf sheet only is available for comparison with a finished sheet, allowance will have to be made for the colour 'going back' a little after sizing.

Among the disadvantages which might be claimed against this method may be mentioned the fact that sizing and drying have to be done at the same speed at which the paper is being made, but we know of two very satisfactory machines on which this method is used, and the speed of the machine has never been affected by sizing or drying troubles.

Of course, a sufficiently large tub and a long or hot enough dryer must be provided to size and dry the paper at the maximum speed of the machine.

A slight variation of this method is to have the machine, size-tub and dryer arranged to follow straight through, but to reel the paper after sizing and then pass it over the dryer.

It is, however, difficult to see what advantage there can be in this, except that the size gets a little time to soak in, for the *last* part of the reel to be sized

is the *first* part to be dried, and supposing that the dryer is run one reel behind the machine, some of the paper will be dried almost immediately, while some of it will have been soaking for an hour or more. Surely this must result in *unequal* sizing, if it is claimed that better sizing is obtained by allowing the paper to soak in the size.

We are of the opinion that in actual practice the difference is negligible between sizing results from soaking and drying straight away. In some mills the making, sizing and drying are carried out in three separate operations, the sizer and dryer being right away from the machine.

This method means that the paper has to be wound up three times and

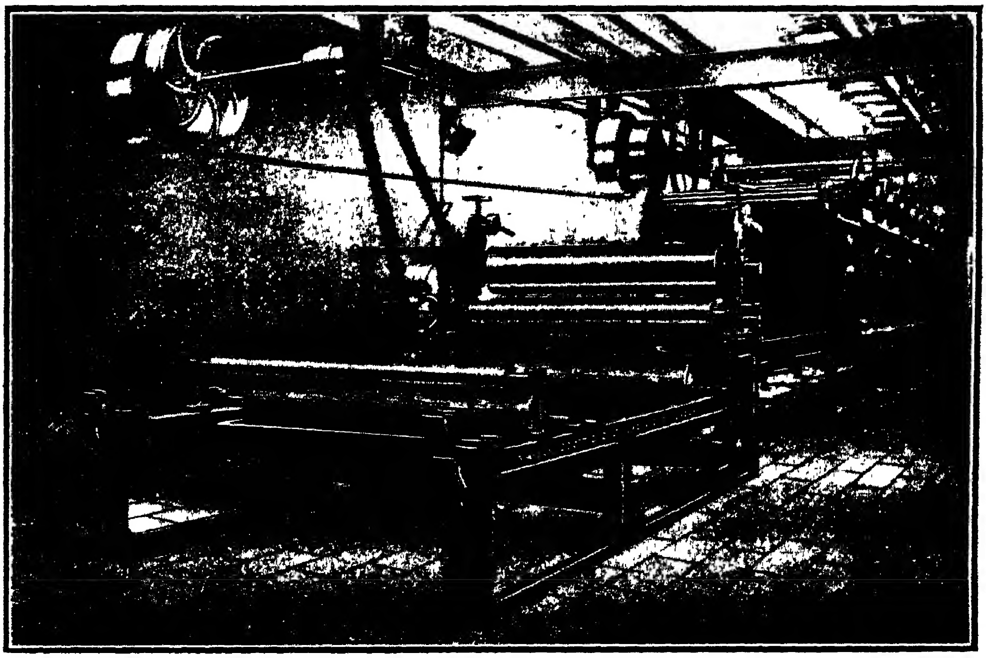


FIG. 129.—TUB-SIZING AND AIR-DRYING PLANT, SHOWING TUB AND SQUEEZE ROLLS, ALSO SPARRED DRUMS OF DRYER

unwound twice, and at each of these operations some paper is spoilt. It also means more labour, as it is impossible to shut down a sizer or dryer to send men to help wash up the machine, etc.

The only advantage which can be claimed for this method is that the speed of each machine can be adjusted to the exact requirements of the paper, and if trouble is being experienced at the size-tub, the machine need not be stopped. The same applies to the dryer.

Another arrangement is to reel the paper at the end of the making machine and then to size and dry it in one operation. This method is the best and usually the most convenient, if it is impossible to arrange all three operations simultaneously. The output of the machine cannot be affected in any way, and

it will usually be found possible to make up any lost reels when the machine is shut for changing, etc.

The web of sized paper is led over the sparred dryers by means of tapes until it reaches the calenders and is started on the reel. The tapes may then be run off the paper to the side of the drums, in order to avoid marking the paper and causing cockling.

It is, however, sometimes necessary to keep at least two tapes on the paper, one above and one below, to keep the web tight and prevent it running off to the side of the drums. It will be an advantage if the spars of the first twelve drums are covered with strips of zinc or copper, as a certain amount of size is always deposited on the spars of the first few drums, and must be scraped off periodically. It is not easy to scrape wooden spars without damaging them, but zinc- or copper-covered spars are easily cleaned with a cloth and hot water.

Trouble is sometimes experienced from paper cockling or creasing at the dryer, owing to the fact that it has not completely expanded in taking up size in the tub. The root cause of this trouble is that the paper is not long enough in the tub, but it can be got over by allowing the web to pass along a travelling felt between the tub and the dryer, in order that it may have sufficient time to expand fully before it is tightened up on the drums of the dryer.

An old wet felt can be utilised for this, and will last a long time, but it must be washed at least once a week.

In the drying of thin banks cockling and creasing can sometimes be traced to the fan speed, and this should be capable of easy adjustment. The speed of the fans is often excessive. If the air is kept in constant agitation and prevented from lying stagnant inside the drums, nothing more is required.

The temperature of the drying room is important, and should be kept at about 85° F. and as dry as possible. Drying is much easier in the summer than in winter, and on a dry day than on a wet and foggy one, unless, of course, specially heated and dried air only is allowed to enter the room, and adequate fans are provided for the complete removal of all air after it has become charged with moisture from the paper.

Very large dryers are usually divided into two or three sections, and these should all be separately driven and have cone pulleys for easy adjustment of the draws.

The drums themselves should be driven by endless cotton belts running on their edges, in preference to cog-wheels, as the draws and tension are much easier, and any slight variation in the size of the drums, due to wearing away of the wooden spars, has less effect in causing uneven tension between drums. Endless trouble from creasing, especially on thin weights, will always result

from unequal draws between drums, if cog-wheels are used, and especially if there are too many drums in one section.

It is often an advantage to have three steam-heated iron drying cylinders at the end of the dryer in order thoroughly to dry the paper after it leaves the sparred drums. These cylinders should have woollen felts, and it will be found that they also assist greatly in flattening the paper before it passes to the calenders, besides enabling thick papers to be thoroughly dry. The heat must not be too great, or the gelatine will be made too brittle, and the strength of the paper will be greatly reduced.

A departure from the usual practice was recently adopted on a machine having 120 drums. These drums were arranged in three tiers, but it was found that the paper was often very flabby, due to imperfect ventilation of the room in wet weather, and also the large number of drums required considerable power to drive. Consequently the bottom tier, which consisted of eighteen 3 feet drums, was fitted with steam-pipes inside and about 3 inches away from the paper. These pipes were led back and forwards across each drum twelve times, in exactly the same way as are the steam-pipes under the hood of some M.G. machine cylinders.

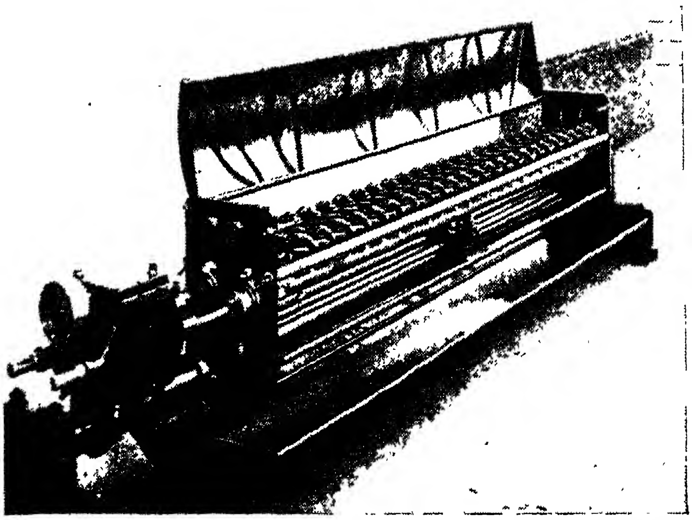
The pipes were divided into three sections, one for each six drums, in order that the heat could be regulated for each section.

When this arrangement was in operation it was found possible to do away with 100 drums altogether, and to get a better dried and harder handling paper with only eighteen drums, and two extra drums with fans but without steam-pipes immediately after the tub. This is, of course, a method that is applicable only to the cheaper grades of tub-sized papers. Theoretically, the best results should be obtained with air at a low temperature and low humidity, but the practical application of this theory is not commercially possible. A very long drying machine running very slowly would be required, and the high moisture content of our air during a great part of the year would render drying almost impossible. Drying machines are therefore as nearly adapted to the general quality of paper made in the mill in which they are installed as experience shows to be approximately correct.

Apparatus for controlling the temperature and humidity of rooms is now available, but is still troublesome and requires a good deal of attention.

DAMPING – SUPER-CALENDER – PLATE-GLAZING – CUTTING – GUILLOTINE – SLITTING AND WINDING – SORTING AND FINISHING

Damping.—The damping of paper is the first step to the finish or surface given by the super-calender. There is little necessity for damping paper that is machine finished, the necessary condition of moisture being obtained by judicious drying. Dryers for tub-sized papers are often fitted with two or three sets of finishing rolls, and the paper is dried soft enough to take a good finish.



[*Sternberg and Phillips*

FIG. 130.—ORION SPRAY DAMPER WITH ADJUSTABLE NOZZLES

But where a higher and finer finish is required, it is necessary to damp the paper to reduce the harshness of the fibres and soften them sufficiently, so that the heat and pressure of the calender rolls can smooth and glaze the surface of the sheet. A paper intended for super-calender finish is usually run through a few nips of the rolls at the paper machine, and is damped before it runs on the reel.

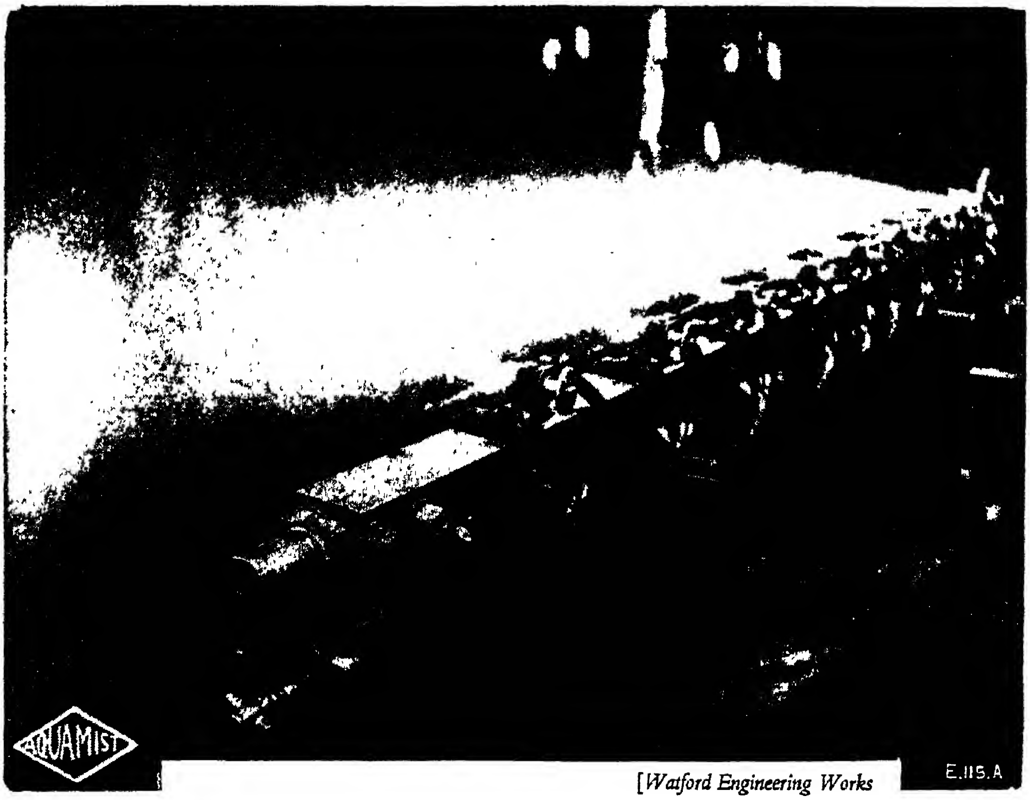
One of the simplest and most efficient dampers is the brush damper. This is a roll brush with hard bristles which dip into a shallow trough of water. As the roll revolves, the bristles carry round a certain quantity of water. This is flicked off by the bristles coming in contact with a doctor blade.

The depth of the water and the speed of the roll are varied to get the required amount of water in the paper.

Another type is worked by means of air jets partly immersed in water

and blowing it on the web. This is very difficult to regulate, as microscopic differences in the orifices of the air jets, and their immersion in the water, make it necessary for each jet to be separately controlled, and the results of adjustments are not fully known until the paper is being super-calendered. Direct sprays have the same disadvantage.

Filtered water is necessary and a high pressure, but under the best conditions



[*Watford Engineering Works*

FIG. 131.—WATFORD PATENT AQUAMIST DAMPER WITH ADJUSTABLE NOZZLES

a small particle of any foreign substance may stop a spray or reduce its volume, causing streaky and irregular finish.

Jets of water impinging on a glass or metal plate, so as to rebound in the form of spray, form a very good damping arrangement, give good results and little trouble.

A form of damper which is now falling into disuse is in the form of a brass or copper cylinder cooled by an internal flow of water. Steam jets are made to play on the outside surface, and the condensed steam in a fine film is transferred to the paper. This form of damper does not give much variation in volume of applied water, and is expensive owing to the use of steam. A felt-covered roll, partly immersed in water, is sometimes used to wet a damping cylinder.

Milne's patent damper consists of a short travelling wire cloth, which is made to carry a certain amount of water in its meshes. Air jets blow this water on to the paper. Any mesh wire may be used as required for the fineness of the spray, and the speed and mesh control the quantity applied.

As only the amount of water carried can be blown on the paper, the damping is very uniform and regular. The cheaper grades of paper are damped on the making machine. Better grades are damped and rewound. All paper should stand for at least twenty-four hours before being finished, so that the moisture will spread through the substance of the sheet and reduce inequalities of damping.

It seems to be a very general idea that best results are obtained by having the paper cool before it is damped. This entails more expense and labour in the use of a damper separate from the machine, but very few mills work this method. The usual practice for super-calendered papers is to damp the web as it is reeled on the making machine, while still in a very hot condition. Quite satisfactory results are obtained. As the damping, or application of water, takes place immediately before the paper is reeled, very little evaporation can take place in the short space of time before the sheet is covered by another layer of warm and watered paper.

As warm water is more penetrative and diffusive than cold, it is only reasonable to expect that it will more readily force its way into the fibres and produce more uniform damping when the paper cools. There is no doubt that the results of practical experience go to prove that the most satisfactory damping is that carried out when the paper is hot off the machine.

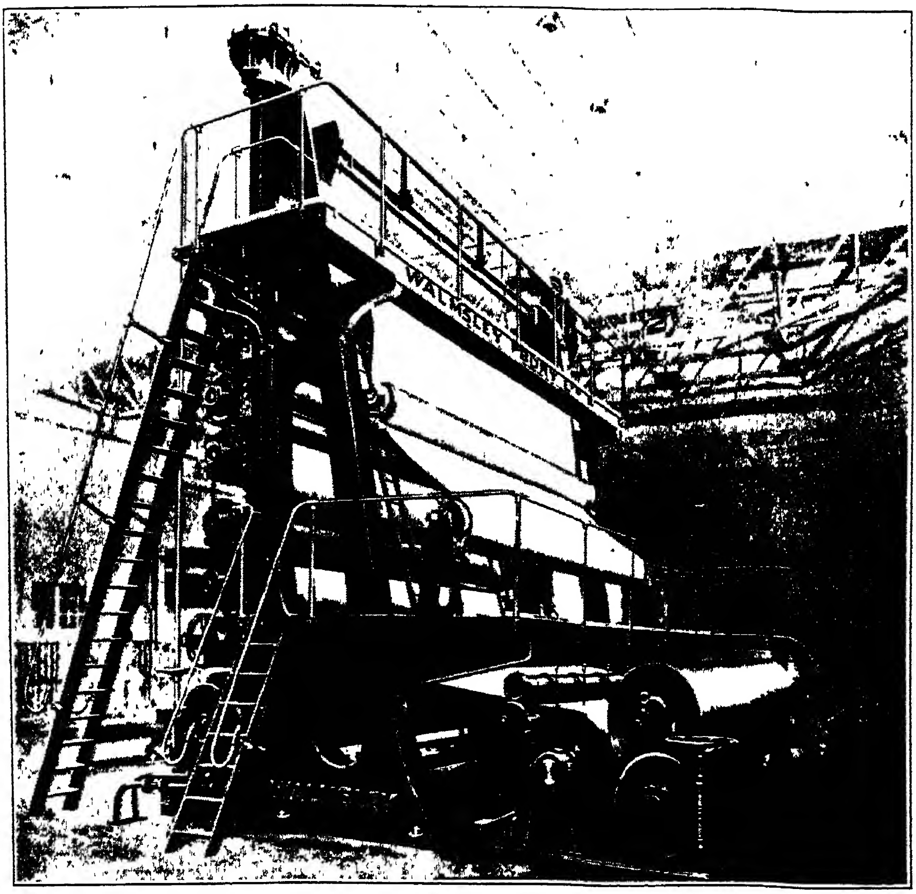
The Super-Calender

The super-calender (Fig. 132) is a stack of rolls usually eight in number, but now being built with as many as sixteen. These are alternately of iron and composition. The latter are built of discs of paper, made from cotton or woollen fabrics and cotton rags and hemp. The laminations or discs of paper are fitted on a heavy steel centre and compressed into a solid form. The roll is then turned and buffed to the correct camber. The iron and paper rolls are placed alternately, commencing with top and bottom rolls of iron. This brings two paper rolls together in the centre of the stack. The reason for the use of iron and paper rolls is that the latter form what may be termed a cushion, allowing the heated iron rolls to impart a high glaze to the paper, without the blackening or crushing and reduction of bulk which take place between two rigid iron rolls.

The two adjacent paper rolls bring the reverse side of the web into contact

with the iron rolls for the second half of its passage, thus giving an equal finish both sides.

The iron rolls are highly burnished and fitted for steam heating. The bottom roll is made greater in diameter than the other rolls, in order to sustain the weight of those above it. The other iron rolls are less in diameter than the paper rolls. As all rolls 'give' under pressure, the calender rolls require



[*Walmsleys (Bury), Ltd.*

FIG. 132.—LARGE SUPER-CALENDER FOR NEWSPRINT

to be very carefully cambered. The weight of the rolls of an eight-roll calender resting on the bottom one would be about 9 tons for a 90-inch machine and about 30 tons with weights full on. This size would take 25 to 50 h.p. at 350 feet per minute, according to the degree of finish and the quality and substance of the paper being treated. The drive is either from the bottom roll or the third from the bottom. In machines with sixteen rolls or more, the seventh from the bottom is the driver, top and bottom rolls being assisted with belt drive, to reduce slip or skid which is very destructive to the strength and bulk of the paper. When not in use the rolls should be relieved of the lever

weights and lifted apart, so as to prevent the line of pressure producing a flat place.

The newer type of calenders have a lifting device for that purpose. They must be washed frequently with warm water and soap, or a little soda, to clean the paper rolls from dust, grit, and resin or gelatine size. Care must be taken not to use too much heat in the iron rolls while this is being done, otherwise they will take the top skin off the paper rolls.

The latter being of a softer nature, any hard substance or wrinkle in the paper is liable to make a bruise or an impression on their surface. For this reason, extra precautions are necessary when working on tub-sized papers; any 'slap' or defect on the deckle edge should be marked with a ticket at the drying machine and damper, and watched for at the calender, as a folded, wrinkled or doubled corner will make a mark in the paper rolls. Hard knots of rag fibre, 'rolls' from the machine apron and ragged deckle edges are to be avoided.

In cheaper papers, the greatest danger lies in particles of metal or grit which become embedded in the rolls and may pass from one roll to another, making so many impressions that the marks become continuous all round the rolls. This is the case when there are no doctor blades on the iron rolls. Many calenders have none except on the bottom roll. A long run on a narrow width web is bad for the paper rolls, as it upsets the camber, the pressure being heaviest on the width covered by the paper. After such a run, the rolls should be cleaned and run as long as possible with frequent applications of hot water and with no weight on.

This will cause the compressed part to swell out to its normal size. Bruises and imprints, if not too deep, may be cured by blowing a steam jet on the damaged place or by applying cloths saturated with hot water. Any deep cut or mark may be improved by a judicious touch up with very fine emery or glass paper and afterwards washing it with hot water. This is a temporary repair and only lessens the mark made on the paper, the proper remedy being to have the roll rebuffed.

This is necessary in any case at longer or shorter periods, according to the hardness of the rolls and the conditions they show after a certain time.

As an additional damping arrangement, it has been found of great assistance to pass the paper through a cloud of steam and over a felt-covered roll before it enters the first roll. Great heat and pressure give a high but not a permanent glaze; therefore, for good class papers, it is better to put the paper twice through the rolls with less heat and weight. When finishing tinted papers, pressure and heat should be kept very regular from reel to reel, as a great many 'shades' may be caused by varying finish.

The mottled appearance of some papers is caused by bad damping—*i.e.*, insufficient time for penetration and spread of the water, or the damper throwing drops instead of spray—cloudy or patchy make of the paper, or strong fibres that will not make a close sheet. In the last case the mottled appearance is sometimes looked for and desired, to show up a strong paper.

Paper intended for a high finish should be specially made for such if possible. The stuff should be beaten so as to produce a close sheet, with the addition of some good china clay and starch. On the machine full use must be made of the shake, and a heavy dandy roll run. If finish is wanted to be equal both sides, the paper must be run through the second press and smoothing rolls to eliminate wire, coucher and felt impressions.

Plate-Glazing.—A plate-glazed finish is applied only to high-class papers. The plate-glazing calender is a machine consisting of a heavy frame carrying two iron rolls. Just under the level of the nip are smooth metal plates, or rollers, both at back and front. The action of the rolls is reversible and the top roll is fitted with levers to apply pressure. The sheets of paper are placed alternately with plates of copper, zinc or cardboard, until a pile, 'book', or 'handful', as it is called, is formed about 1½ to 2 inches thick.

The pile is laid on the metal platform or rollers and the rolls are started. It is pushed into the nip and the rolls grip it and take it through on to the back platform. On the rolls being reversed, the pile is pulled back through the nip. It is then turned half round and the process repeated. The turning of the pile is for the purpose of reducing the curl of the plates and paper and giving the paper equal finish and expansion in the machine and cross directions.

The necessary amount of finish is obtained from the burnished surface of the plates, the pressure and the number of times the pile is put through the rolls. High finish is given by copper or zinc plates, low finish by cardboard. One man works the machine, but it is sometimes necessary to have an assistant turning the pile at the back for low finishes and helping to lift a heavy 'book' from the bench. Women are employed to lay the sheets of paper and metal and to separate them afterwards.

A plate-glazed finish is very fine and silky, and the most permanent of all finishes. An extremely high glaze may be put on the paper, but if overdone the sheet may be crushed out of all recognition. In any case, specks of dirt are shown up very prominently. One may look through hundreds of sheets without finding a single one that is faultless in this respect.

Unless trimmed, the edges of a plate-glazed sheet are slightly rougher than the centre, owing to the difficulty of laying the paper and metal plates so that all the edges coincide.

Plate-glazing is a very expensive method, owing to the labour and time

required, and the extra broke made by the necessity of handling the sheets so often. The hands of the workers are very frequently cut and scratched by the plates, and if a slight injury is not immediately noticed, a great deal of paper may be spoiled by blood-stains.

The crew of a machine consists of four women or girls, with the attendant and an assistant. Practically the only papers that are now plate-glazed are hand-made papers, and some super-quality machine-made writing and ledger papers. The special qualities of silkiness and close texture necessary for the smooth gliding of the pen point cannot be equalled by any other finish, and its permanence is one of the special features of a super-quality ledger paper.

While there will always be a certain but limited demand for expensive plate-glazed paper, this method has to all intents and purposes been superseded by the super-calender; the finish given by this machine satisfies most ordinary requirements. Hand-sized sheets, both hand- and machine-made, are also finished by putting them one by one through a pair of iron or iron and composition rolls, steam heated, and weighted when necessary. After a pile has been put through, the sheets are half turned and then put through a second time. This is a cheaper method, as two women do the work. The paper thus treated is usually sold as 'plate-glazed'.

It may be confidently stated that only an expert can tell the difference between a plate-glazed and a carefully super-calendered finish, and that only when he has good samples of each for comparison.

Linen-faced and other finishes are produced by the same means as described for plate-glazing, except that a sheet of linen of the desired texture is stuck on to the zinc plate or laid between the plate and the sheet of paper. When the 'book' is passed through the rolls the pressure causes the linen threads to make an impression on the paper, and the linen-faced effect is produced. The impression is much greater when the linen is new, and it gradually wears away as the linen becomes flattened.

These papers appear to be losing popularity at present, but they are very pleasant to write upon.

The cost of linen facing is high on account of the amount of labour required and the slowness of the operation, and also the high cost and short life of the linen.

For cheaper papers an embossing calender is generally used. This contains a roll with a linen impression etched upon its surface. The paper is run through in the same way as through a calender and the process is very quick and less costly. The result, however, is not so satisfactory. The embossing calender may be used to give all kinds of 'finish' to paper, such

as 'watered silk', imitation leather and names, designs, which in some cases are almost indistinguishable from water marks.

Cutting.—It is very seldom now that we find a cutter attached to a making machine, but this was once not uncommon. As the old type of cutter, known as the 'English' or single sheet cutter, was limited in speed to under 65 feet per minute, it was found to be uneconomical to keep back the speed of the machine to suit the cutter.

There are still some machines, however, with this cutter attached. These are used for making and cutting high-class writings and drawings 'waterleaf', the sheets being subsequently hand-sized with gelatine, and as a high speed cannot be attained with these papers the objection does not apply.

The 'English' cutter consists of the usual slitting discs or knives, which are common to all cutters, and a reciprocating action chopper. After being slit longitudinally, the paper is run over a large drum. This drum is moved round, carrying the paper to the required length of sheet. The slit sheets fall over a 'dead' knife, and are temporarily clamped as the moving blade swings away and the action of the drum is stopped. The return swing of the table shears off the sheets, which fall on to a moving felt or smooth inclined surface and are 'laid' by hand by boys.

The web slackens back at each stop or clamping, and the slack is taken up by a 'dancing roll', the tension being regulated by two large cone pulleys. The length of the sheet is set by a screw adjustment in the crank which moves the drum, and slight variations are made by hanging small weights on the 'dancing roll' and by a brake which checks the momentum of the drum.

A change of gear wheels enables the crank to make two forward movements of the drum for one chop of the knife for very long sheets.

When cutting short sheets, the speed has to be reduced to under 45 feet, owing to the vibration and the jar of the reciprocating parts. Only one web can be cut at a time. This type of cutter is very accurate in capable hands, and some may still be found doing good work in cutting water-marked papers which must be in exact register.

Under modern conditions of speed and output the revolving cutter (Fig. 133) is now used. The chop knife is fixed on a revolving drum, thus eliminating the reciprocating action altogether. For very short sheets two knives may be used on the drum, but this is seldom carried out in practice, the usual procedure being to cut double sheets and cut them in two on the guillotine cutter.

As many as twelve or more sheets or webs may be cut at one time, according to the thickness of the paper. If the filling is too heavy the bottom sheets may be torn instead of being cut with clean edges. Two rolls thickened at the centre pull the paper into the slitter discs. The tension between the feeding

rolls and the discs is maintained by two steel rolls about 3 inches in diameter. These deliver the slit webs on to the dead knife edge.

The knife on the revolving drum, set at a slight angle so as to have a shearing effect, chops the sheets as they pass over the dead knife, and they fall on to a moving felt. The length of the sheet is regulated by the speed of the revolving drum. This is set by changes of the driving pulleys, and finer adjustment is made by expanding pulleys, enabling water-marked papers to be cut to register.

The carriage of the revolving drum and dead knife is adjustable to cut the sheets at a true right angle to the slit sides. This device is extended so far in the 'angle' cutter that sheets may be cut at any angle. This is essential for reducing waste in stamping out envelopes, etc. A very useful variation of the ordinary cutter is the Duplex cutter, which can cut sheets of different sizes from the same web. This enables the paper-maker to make full use of the width of the machine.

Thus, if the machine is capable of making only 72-inch deckle, and the order is for sheets 30×40 inches, the lot may be made one sheet 30 inches and one sheet $40 = 70$ inches, instead of 2 sheets 30 inches$=60$ inches.

The Duplex cutter has two revolving cylinders and dead knives. These may be driven independently and at different speeds, one part of the web passing over the first revolving knife and being cut at a different length by the second.

An invention which has reduced the labour costs of the cutter to a great extent is the automatic 'layboy'. Formerly it was necessary to have a boy to 'lay' each sheet as it came off the moving felt, so that a cutterman and five boys was a usual cutter crew. With this device which 'lays' and 'jogs up' the sheets automatically, a cutterman and an assistant can manage a cutter.

A cutterman must be very careful and precise with his work. The setting of the slitting discs is a very simple matter. The distance between each fixed disc is accurately set with a good rule, preferably steel. The moving disc is then brought into contact with the fixed disc, and this must be gently done, otherwise the hard edges may chip each other. Indeed, to obviate any risk of this a sheet of thin paper should be used at the point of contact.

A very common mistake is to compress the spring of the moving disc too hard, and thus cause the cutting edges to grate on each other and wear blunt very soon. The setting of the length of the sheet is done in accordance with the table of sizes and pulleys issued with each cutter. The driving belt of the revolving blade must be kept in good order, and well tightened up with the tension pulley or pulleys provided for that purpose.

Before starting the cutter, all tools and spanners should be accounted for

and laid aside. A few sheets must be cut at full speed and carefully measured and right-angled before doing the bulk, and the edges examined from time to time for frayed or torn cuts.

In cutting water-marked papers, the water mark has to be kept in correct position on the sheet. This will often necessitate cutting a fraction over or under the size, as the length between the water marks is liable to vary a little, especially in paper made on a machine with old-fashioned belt and packing drive. A continual watch has to be kept as the sheets pass on the felt, and any variation closely followed and corrected by the skilful use of the expanding pulleys.

It will be recognized that the work of the cutterman, in keeping a good and steady length, depends very much on the care taken by the machineman in setting and working the dandy and the draws of the machine. It is advisable to allow a fraction of an inch *over* the size—say, one-sixteenth—for the cut in water-marked papers.

If the dandy roll cannot be made to register exactly the machineman should notify his foreman, and also send a slip of paper with the reel, to warn the cutterman what has occurred. If the length between water marks is too great, the sheet must be cut to register the water mark, and then trimmed on the guillotine. If it is too short, the water mark will continually run out of register and compel the cutterman to throw out sheets until it comes approximately correct. It will be found on close examination that all water-marked papers cut to register have some variation in length of sheet. This is inevitable to a certain extent, and if the variation is less than ½ per cent either way, the paper may be considered commercially correct. If it is absolutely necessary to have to supply a lot the exact size, the water mark on the dandy roll must be spaced and tensioned to allow for trimming on the guillotine.

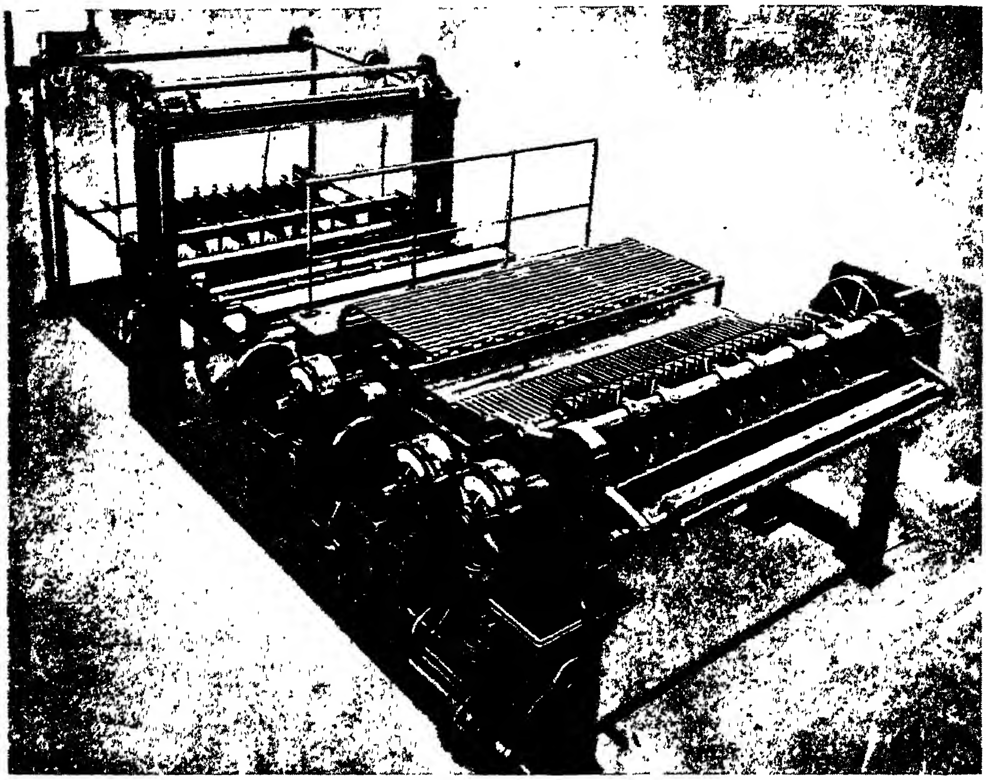
Haubold Supercutter.—This is a modern precision-built machine designed to satisfy the demand for a cutter that will operate at high speed, cut with guillotine accuracy and handle all classes of papers efficiently, whether large or small orders. Cutting speeds of 600 ft. per minute and over are attained.

The machine comprises a heavy feeding press and cutting unit mounted on robust side frames. The feeding press rolls are of special composition, ensuring that all the webs of paper are fed uniformly to the cutting unit. The latter, which is adjustable for true square cut, is driven through a positive, steplessly adjustable gear which controls the speed of the rotating knife and thus enables the length of cut to be accurately regulated.

The drive for the entire machine forms a totally enclosed unit which is mounted on the cutter frame. Every step in the drive is positive so as to avoid backlash, all main drives being effected through totally enclosed, precision,

chrome-nickel steel bevel gears mounted in roller and ball bearings. The machine is direct motor driven through an electro-magnetic coupling which incorporates an overload safety device and an automatic brake for stopping the cutter as soon as the motor is switched off.

The whole of the equipment, while massive and robust throughout, is built



[*Messrs. Masson, Scott and Co., Ltd.*

FIG. 133.—MODERN HIGH-SPEED SUPER-CUTTER WITH LAYBOY

more on the lines of modern high-speed printing machinery than is customary in paper-mill equipment.

The slitter gear, which is situated in front of the feeding press, is provided with knife holders of a new design which give an exceptionally wide clearance for feeding through the sheet. The bottom slitter knives, mounted on a stiff one-piece shaft, are made in halves so that they can be readily changed to enable each pair of slitter knives, and therefore the width of each slit web, to be adjusted simply by turning one handwheel, the width of the web being read off on a graduated scale.

On leaving the cross-cutting unit the sheets are transported to the layboy on a system of conveyor bands. With the latest design of feed the paper run is entirely horizontal right through the cutter. This facilitates handling and

helps to prevent turned-up edges, particularly at high speeds, when cutting only one or a few webs, and also in handling light-weight papers.

The automatic hydraulic overlapping layboy enables the high speed of the cutter to be taken full advantage of. It is actuated by oil under pressure supplied by a pump driven by the main motor. The speed of the layboy carriage is first adjusted to suit the thickness of the bundles of paper by means of a hand-wheel, and thereafter the layboy carriage rises automatically as the height of the stack increases. When the layboy reaches the top of its run it is lowered to the starting position in two or three seconds by simply opening a valve.

As the sheets are delivered from the cutter to the layboy they are overlapped like tiles on a roof, so that they can reach the stack at only a fraction of the speed at which they have passed through the cutter. The sheets are thus easily controlled on the layboy and are not liable to be damaged by the stop board. A system of air nozzles above the layboy conveyor facilitates handling light-weight papers, and a further series of air nozzles at the end of the layboy float the sheets gently into position on the stack.

The cutter and layboy are controlled entirely from a central push-button panel. A number of extra 'stop' push-buttons are fitted at convenient points about the machine to enable the operator to stop it from whatever position he may be in.

There are designs for simplex, duplex, and triplex cuttings, while models are available for installation at the end of a board machine for which the new slitter gear with single handwheel adjustment is used so that the width of slit can be altered while the machine is running.

On the duplex cutters a special coupling is fitted to disengage the duplex unit when cutting simplex only, and an automatic hydraulic stack equalizing device is provided to compensate for the unequal height of the stacks when cutting duplex.

Recently various auxiliaries for these cutters have been developed. Chief among these is a push-button-operated attachment on the drive to the rotary knife drum, enabling the length of cut to be varied by small amounts to locate the water-mark on the cut sheet. Registration of the water-mark is controlled by an operative as he stands at the layboy and watches the overlapped sheets passing to the stack. With this equipment water-marked papers are being cut accurately to register at speeds of nearly 400 ft. a minute.

The ream counter and tabber counts the sheets in reams of 480, 500, 516 sheets as required and inserts a coloured paper strip between each ream. This is all automatic.

When handling papers which are liable to give trouble due to static electricity, the electric neutralizer has proved extremely useful. It discharges the

static electricity in the paper during its passage through the cutter, enabling the latter to be run at higher speeds and minimizes broke. It is quite safe for the operatives and takes practically no current.

It is usual to employ duplicate sets of reelstands so that one set of reels can be loaded while the other set is being run off on the cutter. According to the space available, various methods are used for bringing the new set of reels into position for feeding into the cutter. Where the two sets of reel bearings are arranged horizontally behind the cutter, one above the other, the top set of reels is loaded by an overhead crane in the usual way while the bottom set of reels is being cut. While the top set is being run off, the bottom set is loaded in position by a trolley running on track rails arranged between the stands. The trolley is provided with hydraulic raising and lowering gear.

By another method the two sets of reelstands are mounted on a turnable which is rotated by hand or by an electric motor to bring a fresh set of reels into position. In one case the sets of stationary reelstands have been mounted side by side, and the cutter mounted on a travelling carriage, enabling it to move sideways from one set of reelstands to the other.

The Guillotine.—The guillotine is an essential part of the cutting equipment. Its function is to trim or subdivide sheets cut by the rotary cutter. It is the only cutter used in a 'hand-made' mill. It consists of a heavy frame supporting a level table, on which the sheets are placed. A cutting or shearing blade works diagonally in upright guides. In close contact with the cutting blade is another blade which is blunt on its lower edge. The latter is worked by a foot lever, and is pulled down on the handful of sheets, holding them firm and solid, close to the proposed line of the cut. The cutting blade slides down in contact with this blade with a sideways and downwards motion, similar to that which is made by a knife held in the hand. At the same time power is added to the clamp, to fix the paper more firmly.

The mechanism is so arranged that only one chop or cut is made by the action of pulling over a lever. The blade then ascends, and stops at the top of the guides, and the holding blade is released. The action is assisted by the momentum of a heavy fly-wheel, which is automatically thrown out of action when the knife ascends. An upright at the back of the table is movable to take the required size of sheet. The distance from this upright to the cut is indicated by a sliding gauge at the side of the table, or by a gauge worked by a steel ribbon. A side plate at right angles to the back plate is also provided to enable dead square trimming to be done.

By means of this machine sheets may be trimmed and cut dead square, or 'slit' into small sizes. Small sheets are usually cut double on the rotary cutter and cut into two on the guillotine.

A very common size cuts 40 inches and requires about $2\frac{1}{2}$ h.p. for 'handfuls' of about 4 inches thickness. Smaller sizes are used by stationers, who get their paper in bulk and cut it into writing and ledger sizes.

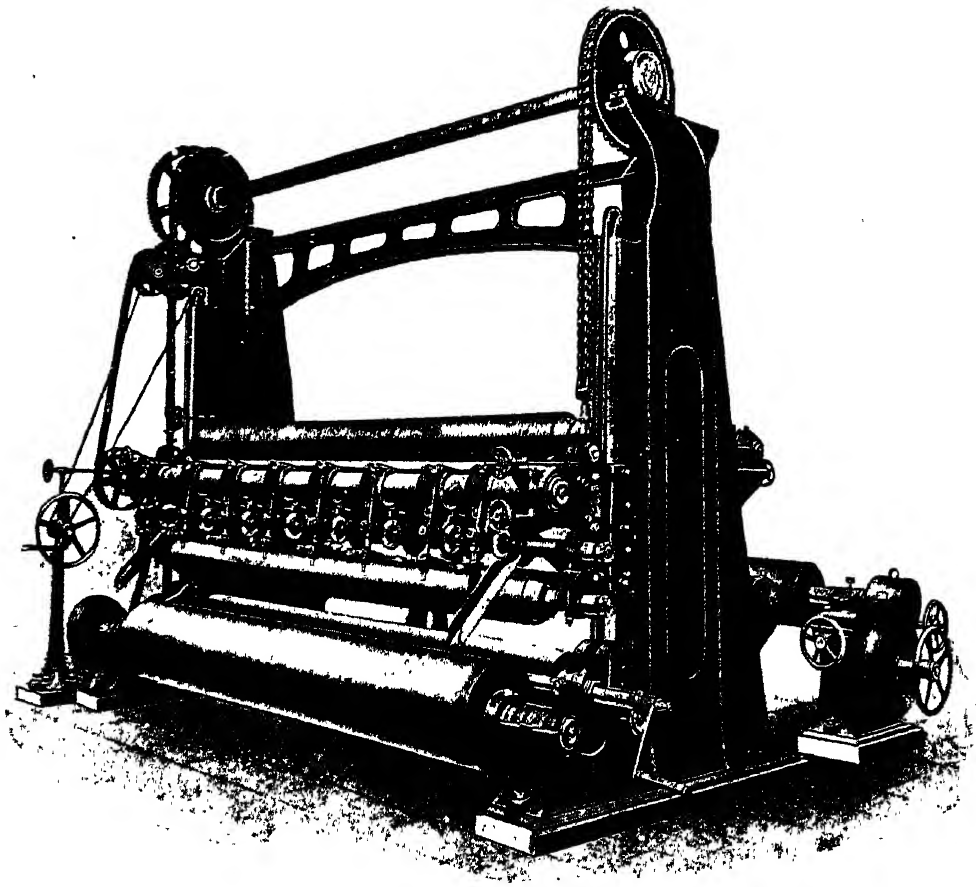
Webs, Slitting and Winding.—As more printing and other processes are being made continuous, the demand for paper in webs or reels in place of sheets is increasing and likely to increase. For this reason the production of paper in reels is becoming of more importance in every paper-mill.

A good reel of paper should be evenly and cleanly slit, and run up to the required size or length with no breaks, cracks on the edges, hard or soft places, or unequal substance and finish. All these cannot be obtained if the paper is poorly made and finished, and faults which would not be apparent in paper cut into sheets become very obvious when it is wound into reels. In the first place, the wire and clothing of the machine must be in very good order. Ridges or dirty streaks on the wire, uneven spread of stuff at the slices, worn or scored couch roll covers, dirty wet felts, badly-cambered rolls, dry felts that have become worn and thin in the centres, unequal couching, pressing, drying, damping or finishing are the most usual causes of bad reeling.

Variations in substance are difficult to check, since the machineman is handicapped by the fact that he must not spoil a web by tearing out and weighing sheets, and has to keep correct substance by other means. An experienced machineman will, however, come very near to being exact by keeping in close touch with his machine. At the end of every reel a piece the whole width of the machine should be taken and sheets marked and cut from the centre and both sides, so as to cover all the width of the paper. Damping and drying should be specially watched, since the success of the super-calender finish will depend on this being regular all across the web. A slight extra damping at any one place will produce a higher finish, which will show as a soft place when reeled. This may be easily so serious as to cause the paper to be creased on the slitter and winder.

Slitters and Winders.—These are of two kinds, friction and drum winders. The friction winder has slitter discs, which are identical with the rotary cutter discs and slit the paper in the same way. Each slit web is wound on a separate spindle by a friction arrangement similar to that on the making machine. This is not a very efficient machine, since the tightness of the web depends entirely on the strain the paper will stand without breaking, so that the webs are soft and bulky. They are therefore very liable to damage in transit and become lopsided on standing or being packed. This causes breaks on the printing machine, as the result of the jerky motion of the unbalanced reel. The drum winder, as its name implies, winds the web by contact with one or two cylinders by its own weight, and is regulated by levers at the spindle ends.

As the weight of the web increases, the paper is pressed harder to the cylinders and wound tighter, which is the reverse of the friction type, where the pull of the friction has less effect as the web increases in diameter. The weight of the levers is so applied that the web can be partly supported to ensure regular pressure from the start to the finish of the reel. In the drum winder all the slit webs are wound on one spindle, strawboard centres of the requisite width



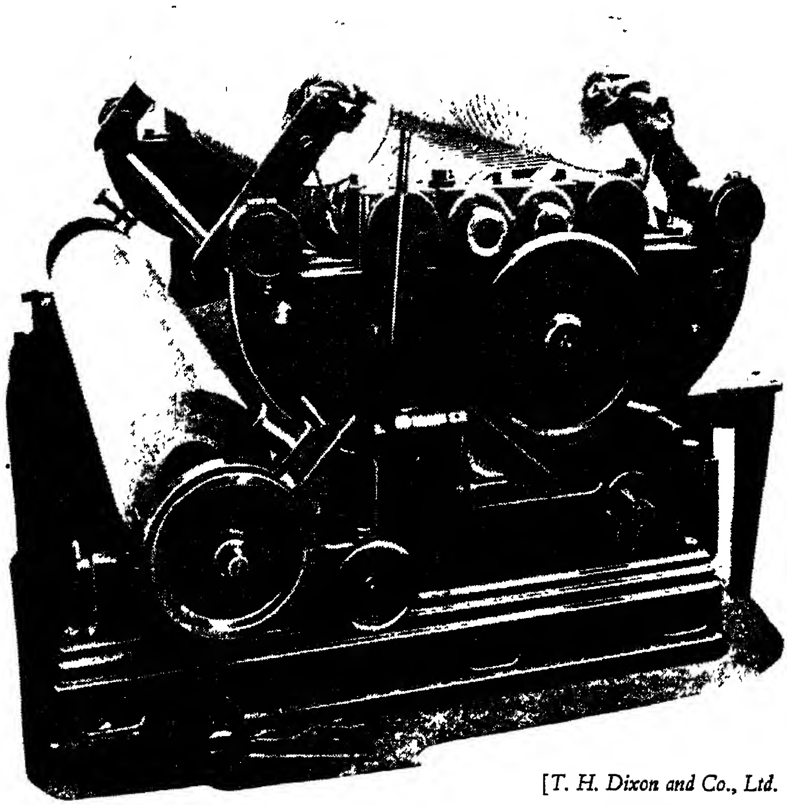
[*Messrs. Masson, Scott and Co., Ltd.*

FIG. 134.—VOITH TYPE HIGH-SPEED SLITTING AND REWINDING MACHINE

being put on the bar and kept tight and in position by an expanding device. The paper is wound by the action of two cylinders travelling close together in the same direction, the webs being in contact with both. The cylinders are sometimes spiralled on the surface, outwards from the centres, to reduce the chances of creasing. If only one cylinder is used, the web is pressed against it by means of levers at the spindle ends, or else it runs directly on top of it. When it is necessary to reel two webs of different yardage a four-drum winder is used. By this means two webs of different lengths may be run off at the same time from the same reel.

A very simple and efficient winder has a cylinder about 9 inches in diameter formed of sections which fit on to a centre. These segments are of various lengths so that slitting knives in the form of thin steel discs may be introduced between them at the required distances. The whole is fixed by screws and lock nuts at each end.

Cutter discs cut the side shavings, but the actual splitting takes place on the cylinder on the top of which the web is run. This machine has the advantage that the split edges cannot run into each other, the cutting discs protruding



[*T. H. Dixon and Co., Ltd.*

Fig. 135.—Dixon Slitter for slitting Narrow Coils and winding on Alternate Bars

from the cylinder about $\frac{1}{4}$ inch. On winders where all the splitting is done by ordinary cutter discs it is often a matter of difficulty to prevent the cut edges of adjacent webs interlocking. It is usual to have a flexible steel bar over which the paper is dragged, and which is bent by set-pins by the attendant into such shapes as to keep the cuts open. On other winders the slitting is done by means of small steel discs attached by rocking levers suitably weighted to a cross-bar. They are moveable sideways on the bar for adjusting to the breadth of the web required. Being fixed between two circular plates $\frac{1}{2}$ inch less in diameter, they are thereby kept from being jammed in the cut by the pressure of levers, and in contact with the web coming off the drum. An attachment

which is almost indispensable for a winder is an indicator showing the length of paper that is wound. Immediately the webs are taken off the winding spindle hard wood plugs should be driven into the open ends of the centres to prevent the pressure from buckling them inwards, as the outside edges of the paper swell by absorbing atmospheric moisture.

When a break takes place the winder is stopped, the broken edges are cut square, and joined with gutta-percha tape or paste. A hot iron is pressed over the join to dry and fix it, and a slip is put in to indicate its presence. A piece torn from the edge should also be marked in the same way.

In order to run good tight webs, such as will run off well on the newspaper presses, it is essential that the webs should be tightly wound from the start, and all joins must be very carefully made, especially at the edges. Voith and Cameron machines are excellent for this work.

Sorting and Finishing.—After the paper has been cut it passes to the 'salle' or finishing room to be overlooked by women sorters, who remove damaged or faulty sheets, and it is then 'told out' or counted by tellers in reams containing a certain number of sheets, after which it is weighed, tied up and put into store, or packed up in bundles of two or more reams and dispatched to the customer.

Obviously this sorting department is a very important place, and calls for very strict and careful supervision if the good name of the mill is to be preserved. Generally speaking, the finer the qualities of paper being made the more careful must the sorting be, for while a few specks of dirt may not be of much consequence in a sheet of cheap printing or wrapping paper, they cannot be allowed to pass in a sheet of good writing paper.

In the sorting room of a mill the light must be good, and must come in through windows facing north if possible, otherwise blinds will have to be arranged on the windows to lessen the glare of the sun. It is always best to get most, if not all, of the overhauling or sorting done during the hours of daylight, and this is of paramount importance if the paper contains different shades which have to be picked out and packed separately.

The girls generally stand at benches with the pile of paper to be sorted on their right-hand side. In front of them they lay the good or perfect sheets, which they 'jog up' periodically into a neat pile. It is usual to have an arrangement of bricks on wooden elbows, in order to form a kind of frame into which the size of paper being sorted will fit. This helps to keep the pile straight and tidy.

If they are sorting three grades—'good', 'retree' and 'broken'—they will need to make three piles, the good in front of them, the retree over on the

left-hand side and the broken at the back. Finally, the bad or useless sheets, such as those with holes, creases and pieces torn off, may be put in a basket, or anywhere else convenient, ready to be taken away to the beater room to be used over again.

According to trade custom good or perfect paper is paid for at full price, retree at an allowance of 10 per cent, and broken, if taken, at an allowance of 20 per cent. The question as to what constitutes a good sheet and a retree sheet must be decided before the paper is sorted, and this is usually done by

[*Abbey Mills, Greenfield, N. Wales*

Fig. 136.—A Well-Lighted Sorting and Finishing House

the salle foreman or forewoman in conjunction with the manager, several factors having to be taken into account. In the first place, the paper must be equal to the sample, subject to the price being paid for it, and subject also to the known requirements of the customer. Some customers are much more difficult to please than others, and seem to imagine that it is possible to get the best all-rag papers absolutely free from specks of dirt. Those who have had a wide experience of the 'fine' trade will know that it is a practical impossibility to get a sheet of all-rag paper absolutely free from all small specks, so that the sorting of such papers resolves itself into the determination of the

amount of specks which may be allowed in a good sheet, and this can only be arrived at by long experience in sorting such papers.

The sorters, who must have experience, while referring doubtful questions to their forewoman, use their own judgment as to what shall constitute a good sheet, and any sheet which does not quite reach this standard is placed on one side to be sold as retree. Those which contain blemishes in the third degree are put among the broken, and obviously faulty and useless sheets are sent back to the mill.

[*Greenfield Paper Mill*

FIG. 137.—EXAMINING, CLEANING, BANDING AND PACKING COILS OF CIGARETTE PAPER

So far we have dealt only with dirt or blemishes in the paper, and these may consist of all kinds of foreign matter, such as pieces of metal from the beater knives, chips from buttons, etc., small pieces of rubber, specks of improperly dissolved dye, splinters of wood, shive, shine, froth and many other things.

Besides dirt, there are other things which may spoil an otherwise perfect sheet of paper; and the women must be on the look out for light or heavy sheets, which must not be allowed to pass, sheets which are too low or too high in finish, and those in which the water mark is defective, or, in the case of a paper in which the mark has to register, is out of place.

In 'jogging up' the sheets the sorter will observe those sheets which are not cut square, or are too long or too short, or cut with ragged edges.

From the foregoing remarks it will be seen that the sorters' work requires experience and skill, and, above all, great care and concentration. A good sorter works at a very fast speed, and rarely allows a faulty sheet to pass, so that she is a valuable asset to the salle, and gets the best qualities to overlook. New sorters gain their experience on lower grades of paper, which do not require such careful sorting. It is usual for good-class papers to be turned as they are being sorted, so that both sides of the sheet can be examined, and during the turning movement the appearance of the 'look-through' of the sheet and also the water mark can be seen. In this way crushed sheets, and blurred or otherwise imperfect water marks, can be seen and thrown out.

It often happens that a small piece of wire, forming part of a letter or design, becomes detached from the dandy roll, and this may not be immediately observed at the machine, so that, unless the sorters are very careful and skilful in watching the mark, they may let through a quantity of paper with the defective mark, and if it is detected by the customer the paper is quite likely to be rejected.

In the sorting of water-marked papers for postage stamps and security papers, which are needle-cut and have to register exactly, it is necessary for each sheet to be placed in a frame with a glass back, in order that its exact registration may be carefully checked.

In order that the work of sorting may be thoroughly and carefully carried out, there must be adequate supervision of the sorters by capable forewomen, whose duty is to watch the sorters regularly, check their work by occasionally resorting it, and removing any faulty sheets which may have slipped through unnoticed. It is also very necessary to watch that a sorter working very fast does not crumple the sheets by rough handling. Many sorters otherwise efficient and careful have this fault, which is mostly the result of gripping the sheets too tightly with the left hand.

After the paper has been sorted it is carefully jogged, and stacked ready to be counted into reams. The counting or telling is quickly done, usually by women, who turn over the edge of a handful of paper and run their fingers across the edges of three, four or more sheets at a time. Often it is necessary to 'quire mark' the reams, and in this case a slip of coloured paper is put in after every twenty sheets.

Unless the paper is specified all 'insides' or each quire perfect, it is usual to place a quire of retree at the top and bottom of each ream, so that if the paper is slightly marked or creased by the tape or during handling, it will generally be the retree quire which will suffer.

As soon as the reams are counted they should be weighed and packed in ream wrappers and fastened with gummed tape; they are then marked with indelible ink lettering as required.

Usually a special brand label is pasted to the ream wrapper, and in this case the wrappers must be thoroughly dried before being used, so that the wet paste will not break through and cockle the paper inside.

When reams are tied with tape the operation should be neatly and regularly carried out, so that when the reams are placed in a pile all the tapes will correspond and give a neat appearance. Attention to these details always helps to give a good name to the mill.

In some cases gummed tape is used for closing the ream wrappers, but this has the disadvantage that it necessitates a fold of wrapper being placed over on to the top of the ream, instead of being folded in at the end, which does not make such a neat package.

When proper knots are used to tie up the tape, the reams can be unfastened quickly and without spoiling the wrapper when only a sheet or a quire or two are required, or when the paper is being examined at the buyer's warehouse.

Before the paper is sent away it is usual to tie up two or three reams into a bundle, and this is done by means of strong and bulky wrappers, in order to protect the paper from damage in transit, and to lessen the handling and packing of it in trucks or lorries.

It is important that valuable papers should be well and securely packed, and sufficient attention is not always paid to this important point. A good paper is worth a good wrapper and will always benefit from it. To realize the importance of this it is only necessary to visit the warehouse of one of the large wholesale stationers, and see the conditions in which the consignments of paper arrive from different mills. Some are neat and untorn, while others are often untidy and the wrappers are all torn and gaping, exposing the paper to light, dust and moisture. While some damage can no doubt be attributed to rough handling in transit, it will generally be found that the packing is greatly to blame.

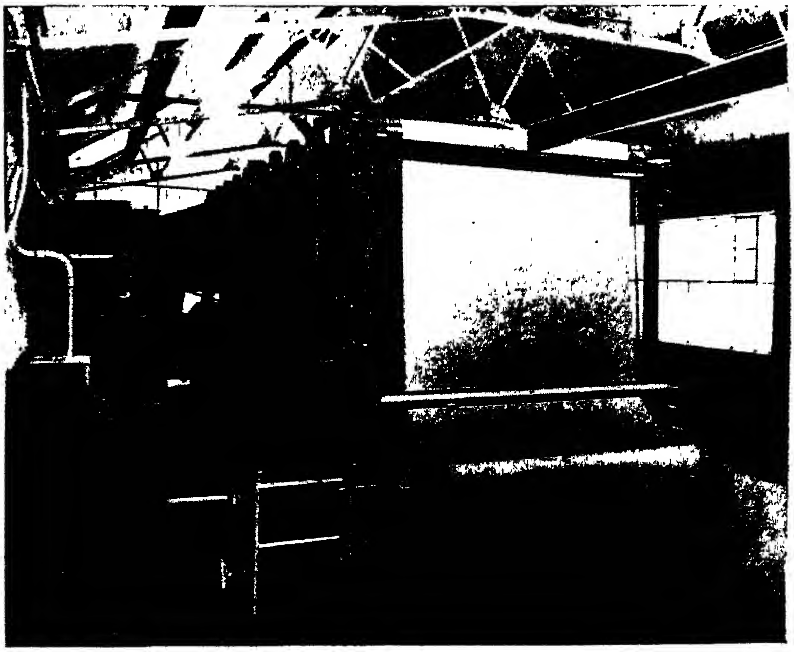
In the case of large and unwieldy reams, especially if the paper is thin in substance, it will be necessary to pack the bundles between light wooden frames or boards, in order to prevent the reams from bending and buckling when being loaded and unloaded.

Formerly, this method was adopted with most fine papers, but nowadays it is generally confined to special lots and unwieldy sizes. These boards and frames are the property of the mill in most cases and are returnable.

Various methods of packing have to be adopted for shipment of paper to

the Continent and for export. Waterproof-lined cases have to be provided for gummed paper for postage stamps, and the lining is usually of zinc; the top layer of zinc is soldered down when the case is full. Other packings require the paper to be baled in a hydraulic press between strong boards with wire hoops.

The overhauling, counting and packing of all other qualities of paper are the same as those for fine writing papers already described, except that the



[*Hall and Kay*

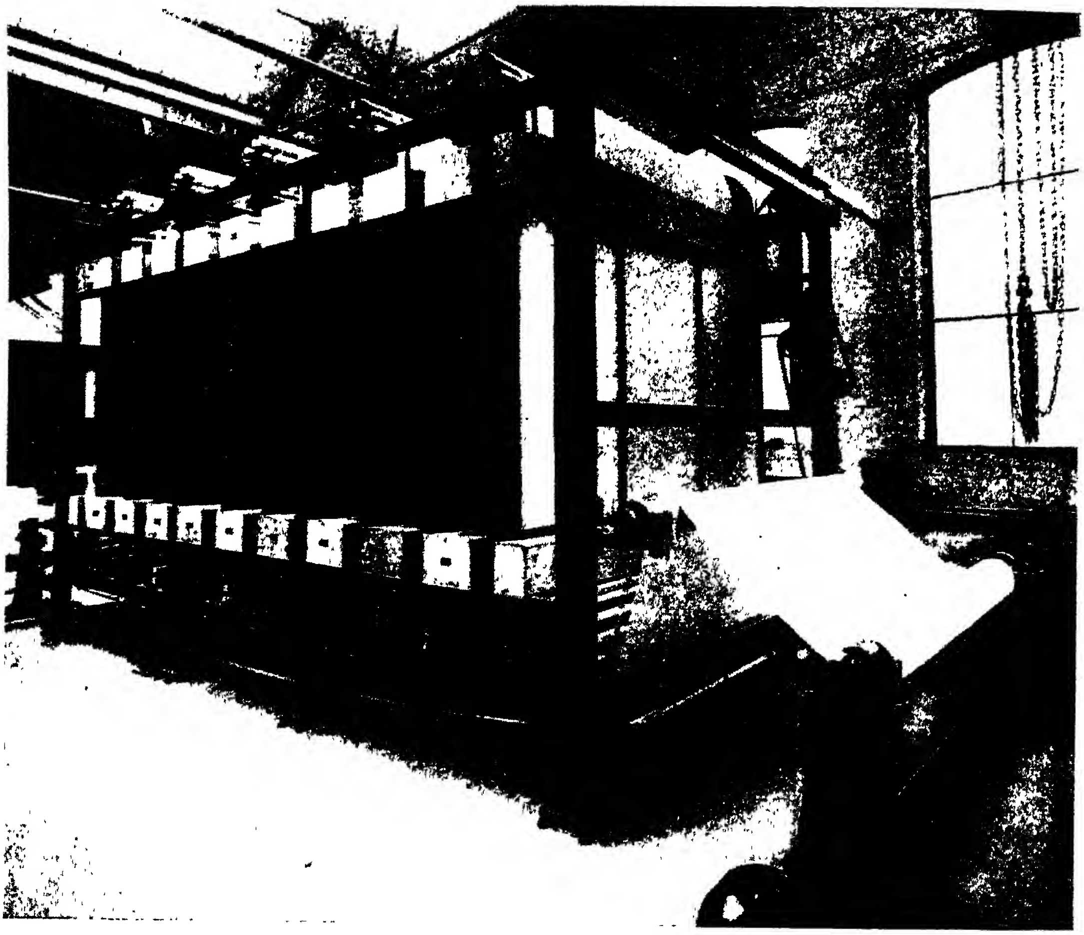
FIG. 138.—HALL AND KAY PATENT PAPER-CONDITIONING PLANT FOR CONDITIONING PAPER CONTINUOUSLY IN MACHINE ROLLS

same standard of cleanliness is not usually expected, and cheaper forms of packing and tying up are used.

Wrapping papers, news off-cuts and cheap papers generally do not have wrappers extending over the ends. In the case of large sheets which cannot conveniently be handled flat, they are folded once or twice, making a more compact and rigid bundle.

The loading of reams and reels of paper into lorries or railway wagons must be very carefully carried out. Straw should be placed on the floor and this should be *dry*. The truck or lorry should be filled as full as possible, so that the reels or reams have no room in which to slide about, and all reels should be securely scotched to prevent rolling. Considerable damage is often done in transit owing to the goods not being properly packed by the sender. Another very general cause of spoilage is the carriage of paper in lorries or

railway wagons that have contained coal or other dirty or oily material. It is here that the value of a mill siding is apparent, as railway trucks can be examined and swept clean, and if the floors are doubtful, a few sheets of coarse wrapping may be laid down to protect the reels or packages. Mill lorries should be similarly treated.



[*Hall and Kay*

FIG. 139.—PAPER-CONDITIONING PLANT, SHOWING THE PAPER PASSING ROUND THE SPARRED DRUMS

PAPER CONDITIONING

Paper conditioning, or maturing, as it is sometimes called, has come into considerable prominence during the last few years, and is one of those additional processes which have been forced on paper-makers by the demands of the printer, who in his turn has been forced to seek for paper which will give him trouble-free running on his fast-running automatic machines. To put it very simply, paper conditioning consists solely in getting paper 'into balance' with what has been termed a 'normal atmosphere', which is generally

accepted as being an atmosphere of 60° F. temperature and 60 per cent relative humidity. In an atmosphere such as this there will be approximately 3.45 grains of water as vapour in a cubic foot of air, and this corresponds to a moisture content in the paper of between 6 and 7 per cent. Paper which is composed principally of cellulose is hygroscopic—*i.e.*, it will take in or give up moisture according to the conditions of the air in which it is placed—and it will alter in moisture content comparatively quickly. This fact is responsible for waviness on the edges of the finished paper. In the majority of mill-finished Fourdrinier papers the moisture content of the finished paper as it is reeled up varies considerably, and can be as low as 1.5 per cent and as high as 4.5 per cent according to the surface given—a very highly finished paper which has been run over hot calender rolls may contain very little moisture; on the other hand, an offset paper which has had less rolling may contain the higher percentage. It is impossible to give any definite figures on this because of the factors which govern this content at the reel end. It will be apparent that the paper is deficient in the moisture necessary to bring it up to the balance with normal atmosphere mentioned earlier. Provided that a normal atmosphere has free access to the paper over the whole of the sheet for about 15 minutes the sheet will of its own accord absorb sufficient moisture for it to arrive at its correct moisture content. Under general mill conditions, however, this free access is not given to the paper; it is reeled, cut, sorted, and packed, and during the whole of that time it is in bulk, and in consequence moisture can be absorbed only by the outside edges of the paper. In the case of a ream it will be obvious that the centre of practically every sheet of that ream will be unable to get air. The outside edges, however, are exposed to the atmosphere and absorb moisture. The absorption of moisture causes the paper to expand, and because that expansion is held back by the unexpanded centre portion of the sheet, the edges develop into a series of waves, and it is this waviness and irregular tension in the sheet which causes the printer so much trouble. Paper-conditioning machines are now available for dealing with this, and all work to the same principle—viz., of passing the continuous web through a number of passes in an atmosphere which will impart sufficient moisture to the paper in its passage through the machine to bring it 'into balance' with the normal atmosphere.

CHAPTER XX

THE TESTING OF PAPER—TRANSPARENCY AND OPACITY—DURABILITY AND STORAGE OF PAPER

THERE are a great many features which require to be considered in the testing of paper as usually carried out at the mill or in the mill laboratory. We have no intention of trespassing on the sphere of scientific research, or of describing intricate processes, but simply to give such information as will be readily understood and ample for commercial purposes.

In the making of all papers it is obvious that some standard for *quality* must be aimed at, and before going further we must define what we mean by *quality*.

This expression as applied to paper is capable of a very wide definition; literally, a paper of 'high-class quality' is one made by hand from the best materials, such as new rags; sized by hand, loft-dried and possibly plate-glazed, and, in fact, a paper of superlative excellence.

In the broad sense of the term, however, a paper may be of excellent quality, no matter what its composition, provided that it is eminently suited for the purpose for which it is to be used.

Newsprint, for instance, may be described as of very high-class quality, and the term may be perfectly correct and logical, though it cannot be said that newsprint, as paper, is of high quality.

Therefore, in testing or judging quality, some standard is necessary for comparison, and as a basis on which to found a judgment. This basis, as between the paper-maker and his customer, is generally defined in terms of price and a certain sample to be matched, this sample being mutually agreed upon at the time the order is placed.

It often happens, however, that a prospective customer sends a sample and wishes to know the price at which it can be matched. Occasionally, too, instead of a sample, a general indication of the kind of paper required is given. If the paper supplied is a good match to the sample, taking into consideration the price asked for it, the customer may consider the paper to be of 'good quality'.

Therefore, in testing paper, quality must be taken as a comparative term, all the characteristics of the paper being placed against those of the sample individually.

For this reason it is necessary to be able to test a sample and ascertain its composition, etc., before submitting an estimate of price, and, later, for the purpose of being able to match it accurately.

Up to within a few years ago—and indeed in some mills to-day—no real tests were made. The manager simply looked at the paper, rattled it, tore a corner, and perhaps compared it with some of his stock lines, and then made a guess at the price at which he could profitably match it. If the customer thought the price too high, he went elsewhere, or offered less until terms were mutually agreed upon.

The paper-maker, having no real knowledge of the composition of the sample, sometimes found his paper returned as unsuitable, or was compelled to concede a reduction in price in order to get it accepted.

As trade and conditions are at present, these haphazard methods are useless. The paper-maker must know exactly the composition of the sample, and he should also know *for what purpose the paper is to be used.* He can then quote a price which, while securing more or less profit for his mill, is still low enough to stand a fair chance of securing the order against other competitors.

If his tests have been fairly accurate he need have little worry as to the results of his making, and by testing the paper at the various stages of manufacture he can check any mistake and produce a satisfactory match to the sample. But as the natural 'cussedness' of paper-making materials, machinery, and workmanship may cause variations during the making of an order, provided these variations do not go very far from the sample, the paper may still, within certain limits, be called a 'commercial match'. The limits of some of the variations, such as substance, are defined by the rules of the Associations of Paper-makers and Stationers. Other variations, such as colour and opacity, which are not amenable to exact measurement, are not so defined, and are left to the decision of the customer.

This leaves openings which are sometimes taken advantage of by unscrupulous firms. A paper, for instance, may be rejected as not being an exact match to the sample for colour. This may be quite true, as it is very difficult, and in some cases almost impossible, to give an absolutely faultless match for colour. After a great deal of correspondence and argument, and threats to withhold future orders, the mill is forced to concede a percentage of the price, and the paper is then accepted. Although the paper-maker is well aware that his paper is a good commercial match, and would be considered so by a competent independent judge, he dare not force acceptance by legal action, well knowing that it may cause him serious loss of trade. Thus the importance of testing paper, so far as it can be tested with certainty, will at once be recognized.

Some of the qualities of paper, as compared to the sample, are matters of individual judgment and opinion; others are capable of being definitely demonstrated.

Constant Humidity.—It has been shown that observations on most paper

tests vary widely on the same sample if tested under different conditions of relative humidity and temperature. An observation of folding endurance carried out at 70 per cent relative humidity may be double the value obtained on the same sample at 60 per cent relative humidity; it has become common practice, therefore, to 'condition' paper specimens before tests are made. The usual recognized standard atmosphere for the conditioning and testing of paper is at 65° per cent relative humidity at 65° to 70° F. It is advantageous that the paper-testing laboratory is a constant humidity and constant temperature room, having double doors with an air lock between and preferably double windows. The walls and ceiling, besides being reasonably thick and heat insulating, are better glazed or gloss painted rather than plastered, so as to reduce the water-absorbing surface to a minimum. The disposal of the paper-testing apparatus in the room must be given careful consideration, so as to avoid the room being unduly large and giving rise to difficulties with air circulation. Provision should be made to supply conditioned air into the room at the rate of about 30 cubic feet per minute per man working in the room. Temperature control of the incoming air, through the medium of a thermostat, does not present any serious problems, electrical heating of the air in winter being possibly the most convenient, and water cooling in summer where necessary, although it may be found that this latter recourse is unnecessary by careful choice of room site. Humidity control is usually brought about through the length changes of a humidity sensitive hair or a sensitized parchment strip. Constant humidity cabinets are also available in which paper specimens may lie for some time before testing in order that their moisture content may attain equilibrium with the controlled atmosphere in the cabinet.

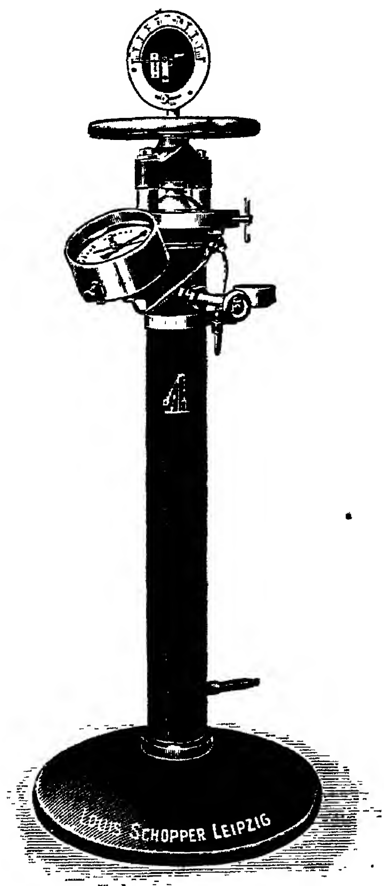
FIG. 140.—THE MULLEN PAPER TESTER FOR TESTING THE BURSTING STRENGTH OF PAPER

Strength.—There are several recognized appliances for testing the strength of paper. The most popular, reliable and easiest to manipulate is the Mullen paper tester (Fig. 140).

In this machine the paper is clamped over a circular diaphragm of thin rubber, 1 square inch in area. By turning a wheel, a piston forces glycerine against the under side of the diaphragm. The latter presses against the paper

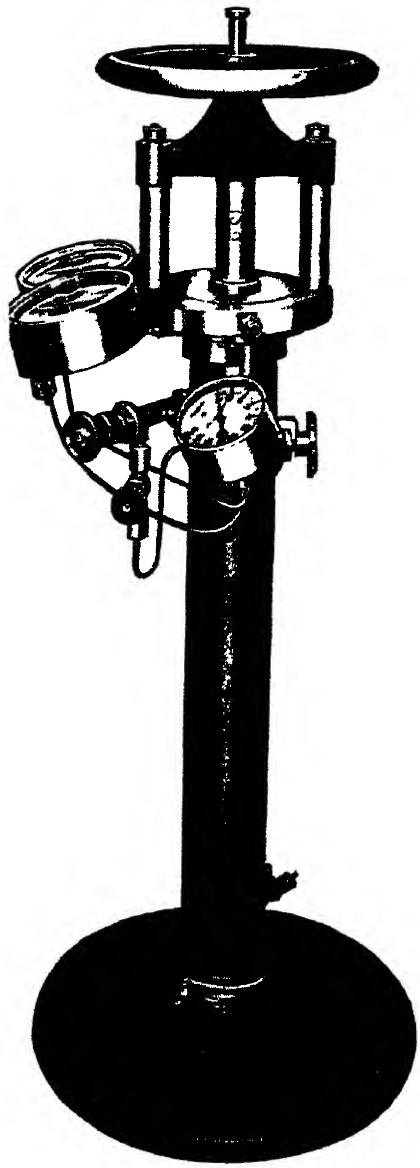
with increasing force until the fibres give way and are pulled asunder. The pressure at the bursting point is recorded on a dial by a pointer.

On a sheet of large post ($16\frac{1}{2} \times 12$ inches) about 12 bursts may be taken to get a correct average. These may be 3 along each long side, 2 along each short side and 2 near the centre. The rubber diaphragms should not be used too long, as they lose their elasticity, and low readings may be expected. Generally the difference between a new and an old diaphragm may be



[*H. E. Messmer*

FIG. 141.—SCHOPPER-DALEN BURSTING TESTER



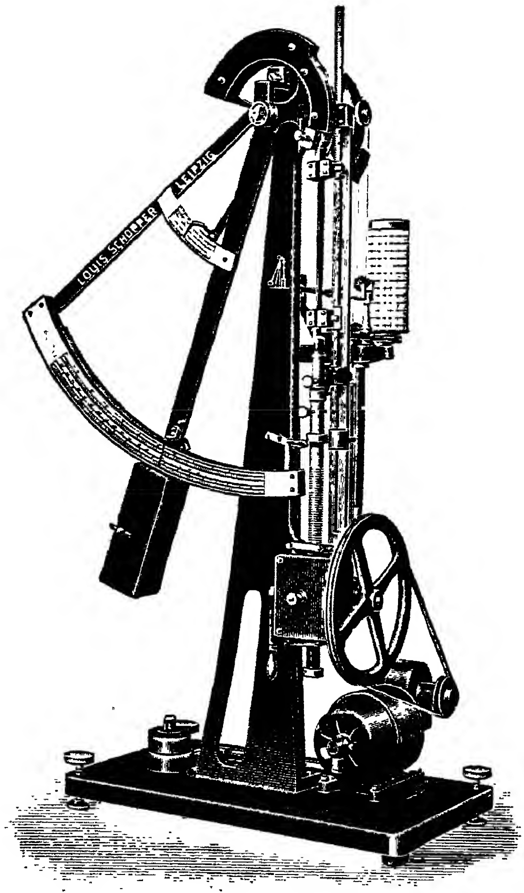
[*Goodbrand and Co.*

FIG. 142.—NEW BRITISH BURSTING TESTER, WITH LATEST TYPE DIAPHRAGM CONTROL MECHANISM

taken as about 10 per cent, but if possible it is desirable to check results by using two testers. If the sample is tested on the same machine as the finished sheet a more accurate comparison may be made.

The paper must be firmly clamped, but not so hard as to produce stress

on the edges of the area to be tested. The rate at which the wheel is turned produces different results. About two to three revolutions per second is a usual speed. A slower speed gives the fibres longer time under pressure, when less is required to tear them apart. A uniform, not jerky, movement of the wheel is essential. The highest bursting point of paper is reached at normal humidity, about 5 to 8 per cent moisture. If the paper is above or below this moisture content, lower readings are obtained. It is as well to remember that a paper newly made may be expected to gain up to 10 per cent increase of strength when properly matured. Sometimes different readings will be obtained according to whether the top or under side of the sheet is clamped next to the diaphragm.



[*H. E. Messmer.*

FIG. 143.—SCHOPPER TENSILE TESTER ARRANGED FOR ELECTRIC DRIVE

The sheet may be tested both ways. Two operators sometimes get different results on the same sheet, but two experienced men generally come very close in their averages.

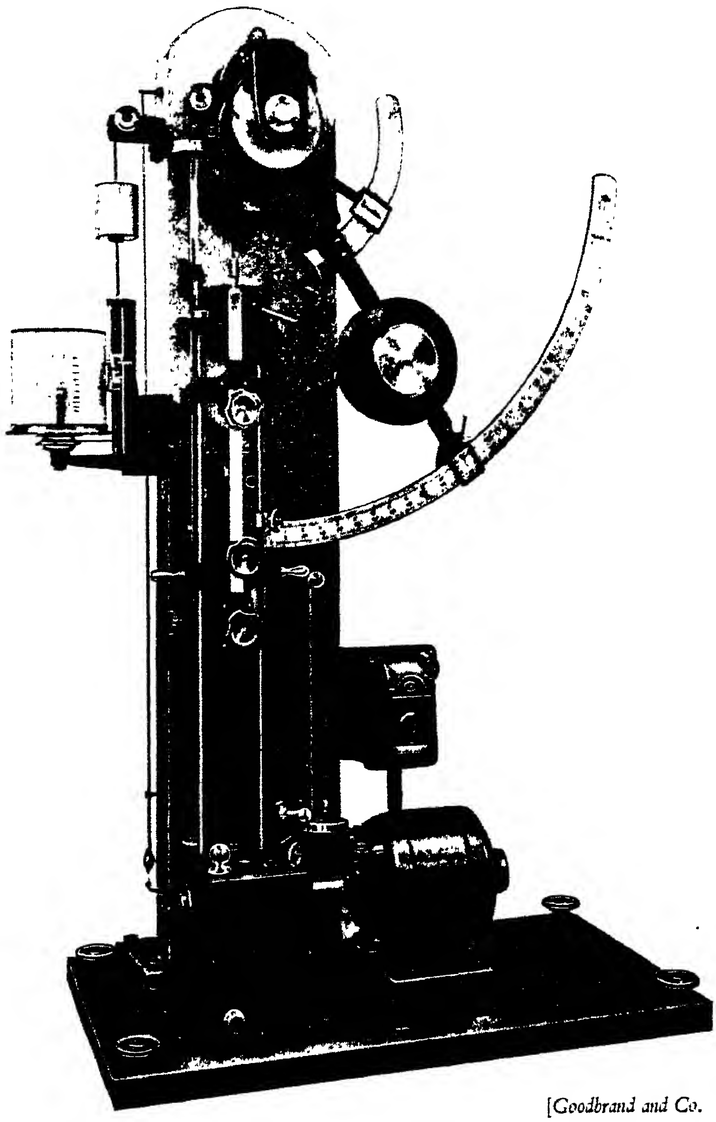
There are other paper testers of this type, such as the Ashcroft and Schopper-Dalen, but they all work on the same principle, differing only in structural details.

Certain modifications have been recommended for use with the Schopper-Dalen type of tester in the diaphragm pressure control mechanism. These are incorporated in the more recent instruments made by Goodbrand, of Stalybridge, the latest of which is illustrated in Fig. 142.

Whenever possible, the operator who tests the sample should also test the finished sheets of the paper. In connection with these tests, it is necessary to point out that there is no corresponding proportional increase of bursting strength as the substance of the paper increases. Some paper buyers seem to be under the impression that this is so, and we know of an instance where a sample was sent to be matched for quality, but the paper had to be of a much heavier substance. When the sheets were sent in, the paper was

rejected, because the bursting strain did not increase in exact proportion to the substance.

The Schopper paper tester (Fig. 143) is a modern adaptation of the old method of paper testing. Before the introduction of this machine, a strip of



[Goodbrand and Co.

FIG. 144.—TENSILE STRENGTH AND STRETCH TESTING MACHINE
This is the latest and most improved type and is British made

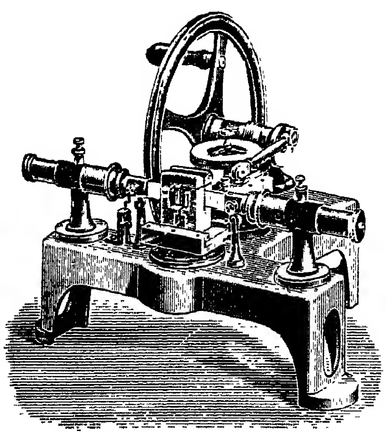
paper of a certain length and breadth was suspended from a clamp; another clamp was attached to the bottom of the strip and weights were added until the strip broke. When the Schopper is used, the breaking strain of strips cut from across the web, and also in the machine direction, is taken, and a short

calculation gives an average or mean breaking strain. The strip of paper, fixed between two clamps, is used to raise a heavily-weighted lever by means of a wheel and gearing.

The lever remains automatically fixed by a pawl at the point where the strip is broken, and a graduated scale and pointer show the breaking strain in pounds. In addition, the stretch which has taken place is also recorded.

Like the Mullen tester, the Schopper requires the wheel to be steadily turned, and where great accuracy is required this may be done mechanically by a small electric motor, or by means of hydraulic pressure. Older machines of this type depend on a spring for the tension, and they are accurate enough on the whole, but as the Schopper machine is the standard tester, they are falling into disuse.

The more recent motor-driven instruments of this type, by Goodbrand—illustrated in Fig. 144—have a two-speed gear box giving alternative loading rates, and a graphic recorder indicating the stress/strain diagram of the paper specimen examined.



[*H. E. Messmer*

FIG. 145.—FOLDING TESTER

When using these machines which require a strip, it will be found that strips cut in the machine direction have a greater tensile strength than those cut across the web. Hand-made papers show little difference owing to the shake being applied in both directions during making.

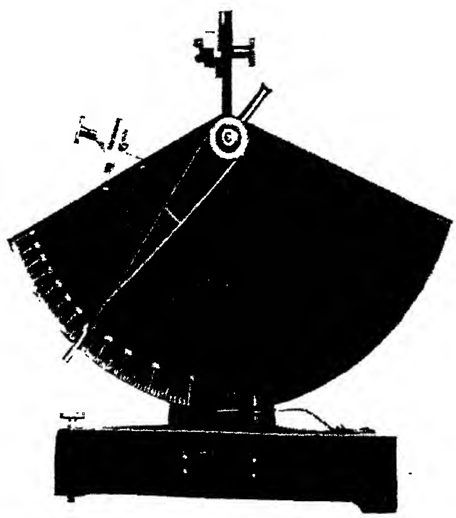
While the Mullen and Schopper types do not show results in any relation to each other, it will be found in practice that either machine will bear out the evidence of the other.

Folding.—Closely allied to the question of strength is that of 'folding'. Envelope papers, paper for bags, etc., require to be capable of being folded without danger of the paper breaking at the hinges and folds.

Folding Endurance.—The most widely used instrument for the determination of folding endurance is that by Schopper (Fig. 145). A strip of paper cut to a standard template is clamped under a known arbitrary tension and subjected to a continuous backward and forward folding effect. This folding effect is produced by a slotted steel plate, which through a reciprocating motion folds the strip until fracture takes place. The number of folds required to produce fracture is recorded on a dial, the operating mechanism of which stops at the time of breakdown. The number of folds that a given paper will stand before fracture occurs under a given tension offers a fair indication of its cohesive properties.

It is essential that the folding endurance test is carried out in a constant humidity room, since this test is very susceptible to change in atmospheric conditions. A folding endurance carried out at 70 per cent relative humidity may be double the value obtained on the same sample conditioned and tested at 60 per cent relative humidity.

Tearing Strength.—It has been claimed that the tearing strength is a better criterion of paper strength value for practical purposes than either the tensile or bursting strength. A popular instrument for the measurement of tearing strength is the Marx-Elmendorf (Fig. 146). A specimen of paper is accurately cut to a template in such a manner that two parallel slits form a centre tongue, the equivalent of the start of a double tear. The outer tongues produced by this cutting are held in a fixed clamp, while the centre tongue is subjected to the load of a pendulum to continue the tear. The load necessary to continue the tear is recorded through a spring-loaded friction pointer on the scale forming the pendulum. Thus the instrument records the work done in continuing a tear in a given length of paper, and not the resistance of the paper to the starting of a tear. The magnitude of the tearing force as determined above is very small compared with the breaking load under tensile stress for the same sheet of paper. Like the tensile strength, it is possible to determine the relative tearing strength in both 'machine' and 'cross' directions, a factor offering some indication of fibre orientation in the sheet.



[*Renold Marsh*

FIG. 146.—ELMENDORF TEARING TESTER

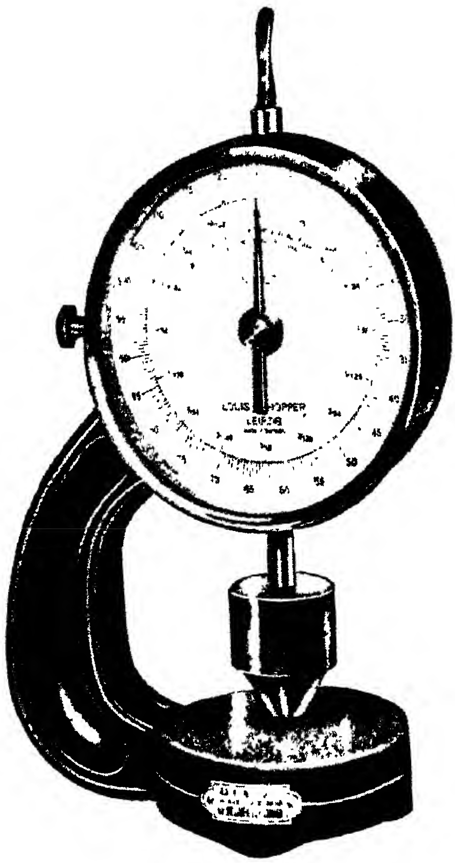
Thickness.—The thickness or 'bulk' of paper is measured by small instruments known as micrometers (Fig. 147). These are very delicate instruments graduated to thousandths of an inch, and they work either by spring pressure, which is always constant, or by means of a fine screw, the head of which is fitted with a friction arrangement, so that when the face of the screw presses the paper against the fixed face the screw cannot be turned further, and so the paper is not squeezed.

The spring micrometers have a dial, divided into thousandths of an inch, and a pointer shows the thickness of the paper under test.

It is usual to place four or more pieces of paper in the tester at a time, for in this way the ever-present irregularities in the surface of the paper are taken into account, and it is obvious that this is necessary

if the thickness of the paper is required to give any indication of the bulk of a book, etc.

Substance.—The substance, or weight per given area, or more commonly the weight per ream of a definite number of sheets, is ascertained by means of a pair of scales and weights. The paper is cut to the required size, such as 20×30 inches (double crown), $17\frac{1}{2} \times 22\frac{1}{2}$ inches (demy), $16\frac{1}{2} \times 21$ inches (large post), and a sheet of this size is weighed, either by a balance scale and special weights, or in a special lever scale, which has a graduated quadrant plate, on which is engraved the weight per ream of 480, 500, or 516 sheets. In these latter scales a sample sheet of any desired size may be weighed, so that it is an extremely useful instrument for the machineman to have on his table, enabling him, as it does, to cut a sheet of the exact size of the finished paper and weigh it, thus avoiding the necessity of calculating the weight in the usual mill standard size, such as double crown, etc.



[H. E. Messmer

FIG. 147.—MICROMETER THICKNESS TESTER

It is usual in mills making paper of many distinct sizes and substances to have metal templates for all the more usual sizes, so that the machineman may quickly cut out a sheet for checking his weight.

Air Permeability.—The permeability of a paper to air is a guide to the degree of calendering, coating, sizing, or beating. The two most popular instruments for this determination are the Potts permeability apparatus and the Gurley densometer. The former is readily constructed from simple laboratory materials, and has the advantage over the Gurley instrument in that the determination is made at constant pressure. The sample of paper is held in a clamp of known dimensions and air is drawn through the sheet under constant pressure by means of a water aspirator fitted with a Marriotte tube. By measurement of the volume of water passing from the aspirator in a given time it is possible to report the air permeability of the paper as volume per unit time for air passing at a given pressure through a known area. A mathematical interpretation of the significance of observations by this apparatus has been given.

The Gurley densometer operates by allowing a cylinder of specified characteristics, having a specimen of paper to seal its upper end, to fall freely in a second cylinder containing oil. The paper is clamped between two orifice plates having an opening of 1 square inch, and the inner cylinder is timed for a given fall equivalent to a known volume of air being displaced through the paper at the upper end. The permeability is then reported as the time taken for the displacement of 100 c.c. of air. An improved type of this instrument is now available in which the inner cylinder is sealed at the top and air is forced through an inner tube extending to a paper clamp at the base of the instrument. It will be noted that the Gurley densometer does not permit the passage of air through the paper specimen at constant pressure.

The Gurley smoothness tester is a development of the densometer. By this device both sides of the sheet are subjected to an equal air pressure by the equivalent of a densometer falling cylinder. The paper is supported between two optical flat steel blocks with a centre opening connected to the falling cylinders, so that the passage of air is outwards between the face of the sheet and the steel block. The rate of flow of air across the sheet is determined by inequalities in its surface, and so is a measure of smoothness and 'finish'.

The degree of sizing of paper is usually measured by the rate of water penetration. By means of the Currier apparatus the time is determined in which a sample of paper is penetrated by water, the sample being placed on a metal plate and covered with a wet felt. Liquid penetration has been followed by a change in the light reflection on the upper surface of a paper sheet due to a liquid penetrating from the under side, the reflection being followed photo-electrically.

Of interest to the printer is the softness or compressibility of paper. The Bekk hardness tester is used for observations on this property. The instrument consists of a metal cylinder with a spherical end attached to a rod and free to move in a vertical plane like a pendulum. The paper sample is clamped against a hard steel plate vertically below the pivot of the rod. The metal cylinder is withdrawn through a standard arc and after lightly inking the spherical end is allowed to impinge on the paper sample. The area of the ink spot produced on the paper is a measure of its compressibility.

The rebound arc of the cylinder is also measured, since this affords an indication as to whether the paper will be permanently deformed and embossed, after printing. A paper with a small rebound arc, and therefore low elasticity, may be permanently indented during printing.

Another attempt at deriving a numerical measure of a rather obscure paper property is afforded by the Bekk resistance to 'picking' apparatus. 'Picking' is a difficulty experienced on printing machines where small

surface areas of paper become detached and adhere to the printing rolls. It is claimed that this apparatus indicates the relative freedom from 'picking' in different papers. While the apparatus may give a broad indication as to the relative merits of different papers, the conditions of the test are not strictly comparable with those encountered in practice on a printing machine.

An instrument is offered by Schopper to measure the ink-absorption properties of blotting papers. The same manufacturer is also putting out a continuous bending tester which it is claimed has overcome some of the fundamental failures in the design of the folding endurance tester.

During recent years the optical properties of paper have received much attention, and at the moment quite a number of instruments are marketed to determine both the opacity and gloss of paper. The use of some of these instruments is restricted to the routine checking of batches of similar papers and do not give reliable observations on papers of widely different characteristics. In the main their operation depends on the measurement of the amount of light from a standard source passing through the sheet (for opacity) or reflected from its surface (for gloss) through the medium of a photo-electric cell. The choice of the photo-electric cell is important, it being essential to use a cell system with the same colour response as the average human eye. Amongst the more popular instruments for this purpose are the Westinghouse Trans-O-Meter, the Bausch and Lomb Opacimeter, and more recently the Lange reflection meter. A very high sensitivity in the measurement of whiteness is claimed for the Leukometer (Zeiss).

Composition.—A knowledge of the nature of fibrous materials of which a sample is composed is of very great importance to the paper-maker. On that knowledge the price is estimated; without it he may make serious mistakes.

Suppose, for instance, a sample is submitted and a price agreed on to match it in all respects. The paper offered may be all right in all details, but may contain a fibre that the customer does not want, and is not in his sample. He would be quite justified in rejecting the making. It is not at all unusual for papers containing wood fibres to be offered as matches to 'all-rag' samples either through ignorance or a desire to make a little more profit, or to get the order at a 'cut' price.

The microscope is a very necessary piece of apparatus in the identification of the constituent fibres of the paper furnish, and useful work may be performed with relatively simple apparatus. We have already (see Chapter I) indicated the chief points of difference in the various fibres, and little difficulty should be encountered in recognizing them. The paper specimen is disintegrated and stained for examination, the Hersberg stain probably having the most wide application. Whilst different fibres assume a different tint by the stain, this characteristic

tint is not the true medium of differentiation, the function of the stain being to exaggerate the characteristic appearance of the fibre. A table of colour reactions on fibres by the more commonly used stains is given in the Appendix. Furnish may be approximately estimated by a count of the different fibres present, although beating adds to the difficulty of such an estimation.

Transparency and Opacity.—Transparency in paper depends on the comparative absence of light reflecting or absorbing faces or facets in or on the fibres, minerals or other items of its composition. Any treatment—parchmentizing, waxing, finishing, fibrillation, or the addition of such substances as size, starch, etc.—which tends to cause the fibres to pack closely together and eliminate or fill up air space produces transparency by allowing light rays to pass through the sheet more or less unbroken or unreflected.

For example, vegetable parchment before and after treatment. This paper is beaten free and consequently is very opaque, but after the manufacture is completed it is the reverse. Blotting has its opacity from its bulk, which is the result of quick and free beating with very sharp tackle, and the softness and want of felting qualities given to the cotton fibres by treatment. Yet the same furnish may be treated to produce a comparatively transparent sheet, if highly fibrillated, sized and finished as a writing paper.

Envelopes to match must be opaque. To get this result the fibres must be beaten long and free and, if possible, china clay and a lower quality of fibre may be utilized.

The second press should not be used; this omission will give a little more bulk and leave the under side of the sheet with a rough surface. All fillers and colours of a mineral or pulpy character produce opacity. So also do all dyes when used to get a deep shade, but a slight addition of a good blue dye will give an increased transparency to paper. A poor or cheap colour always gives a more opaque result than a good colour, owing to the greater quantity required to produce a similar shade.

The transparency of paper generally is a good indication of the quality; the better the quality the more transparent will the sheet appear, owing to the greater care that has been taken in boiling and bleaching the fibres, and the purity of the colour, size, etc. A finish given on the machine with iron rolls gives a more transparent paper than the super-calender or plate glaze, owing to the greater compression and loss of bulk. The colour and quality of water used at the mill influence the transparency of the paper, so that one mill will have difficulty in giving the opacity, and another the transparency or purity.

In the first case the stock may be dulled down with a touch of nitrate of iron, and brought up to the colour with blue and pink; in the second, it may be necessary to use a higher grade of stock and to touch up the shade with dye.

The use of broke or waste paper that has been boiled gives opacity, owing to the boiling having reduced the colour of the fibres.

The Durability and Storage of Paper.—In the hurry of modern paper-making the durability of paper is a subject that few paper-makers seem to consider. A hundred years ago paper-making was a slow, not to say leisurely, process, when the result of the paper-makers' labour was a thing to be prized and taken care of. Books were carefully bound and treasured as lasting records, and from first to last the art of paper-making and bookbinding was conducted with the object of producing an enduring article.

With the advent of machinery this ideal began to change, not because of the greater output that became possible, but because progress demanded that output. The slow, old-fashioned methods and materials were too expensive, and other and quicker methods, and cheaper and more abundant materials, became necessary if paper-making was to keep up with the advance of science and the general progress of the world. This inevitably meant poorer and less durable products, but it was recognized that these were quite good enough for what was required of them.

Now this idea has developed so far that no one troubles about paper further than that it will fulfil the purpose of the moment, and that it can be obtained at the lowest possible price consistent with that condition. The paper-maker is now compelled to supply demands on that basis, and when we have complaints from printers and stationers about the paper they receive, we feel tempted to reply that they are getting no more and no less than they are paying for.

Any of our 'fine' mills can supply a paper that will last, under ordinary conditions, for ever, but very few printers, for instance, would be willing to pay a price that would enable the paper-maker to make that paper. The object of the paper-maker is to supply the best he can for the price, and this best too often falls short of the quality he would prefer to give.

There are, however, papers that are admittedly made for the moment. They serve the purpose and are discarded. The principal paper of this class is newsprint. All papers containing mechanical wood are short-lived. The resin and natural impurities in the wood very quickly bring about the destruction of the paper, which turns brownish-yellow in colour, grows brittle and ultimately is reduced to dust. Newsprint does not work well on the printing machine when newly made. It is all the better for standing a few weeks to absorb the normal humidity of the atmosphere, and to allow any electric charges to pass away.

But within ten years after being used, newsprint generally is so much deteriorated that it can scarcely be handled. It may be preserved by pasting

a thin tissue of good quality over it, but it is doubtful how long a newspaper will be readable even with this plan.

On the other hand, news-sheets printed 100 years ago on hand-made rag printing paper are as good as ever. One of the greatest factors in the deterioration of paper is the use of resin size. Resin, when exposed to light and air, becomes friable and is reduced to dust, and all papers sized with resin lose their ink resistance, colour, strength and finish. When resin size is supplemented by a coating of gelatine the life of the paper is lengthened, by how long we cannot tell yet; but it is certain it will not in 100 years be in the same perfect preservation as when it was made, as the hand-made papers of a century ago are at the present day.

By substituting silicate of soda for resin we get a much more durable and light-resisting paper, such as may be used for printing with printer's ink.

As regards dyes, many cannot stand light at all without fading out and taking all the good of the paper with them. The aniline or coal-tar products are mostly of this class. Smalts blue is, of course, a permanent colour, so also in a great measure is good ultramarine blue and most of the mineral colours, except those which owe their shades to oxides of iron, and which tend to go darker in colour and destroy the cellulose.

Chemical residues of alkalis, bleach, acids and possible combinations of chemical traces in mill water many cause or hasten deterioration of paper. A very curious effect is produced by age in the particles of copper or brass that are found in a great many good papers that have been beaten with bronze roll bars, or that have been made from rags in which pieces of copper have been retained. In a few years from each of these particles irregular lines spread outwards through the fibres, sometimes covering a space ¼ inch in diameter. These are called 'dendritic growths'. The products of the oxidation of the metal travel along the fibres and form fern-like designs.

While the paper-maker knows that many of his products are more or less perishable, he is also aware that some or all can be greatly improved by being kept in stock for varying lengths of time, under proper conditions, before being sent out from the mill. All machine-made papers are produced under a certain amount of strain, and the fibres ought to get time to relax.

Most printing papers are improved by being kept in a cool, dimly-lighted stock room for a few weeks. Papers intended for litho work especially will benefit by absorbing atmospheric moisture and getting rid of their electric charge.

On gaining a normal air-dry condition finish goes off more or less. A plate-glazed finish is most permanent; next in order is a super-calender finish. Any glaze or finish obtained by hot rolls is most liable to go back. But a

wise paper-maker provides for this by having the finish a little higher than the sample in the first place. Complaints are often made of deficient bulk and too high finish when all that is required is a reasonable time for paper to mature. For this reason it is bad policy for a customer to send an order and ask for *immediate* delivery, unless he knows the mill stocks the paper he wants, and also for the paper-maker to delay making an order until he has to send it out as soon as it is made.

Poor quality or badly-made gelatine size is also a common cause of the deterioration of paper. Given the least extra humidity in the stock room, poor size begins to give off an offensive odour, and the paper loses strength, colour, finish and ink resistance. Generally a good quality of gelatine size, properly made, will withstand the ordinary variations of humidity in the stock room, but any definite dampness continued for a time produces bacteria which destroy the gelatine.

Paper should not be stocked on a ground floor or under ground level, where the atmosphere is likely to be humid. A well-ventilated stock room on the second floor is most desirable, with a temperature of 60° F. and a diffused light from ground-glass windows, preferably greenish-tinted.

All ventilators should be covered with wire cloth, to prevent dust or sooty particles from gaining admission, and no machinery or shafting should be installed in a paper store.

Sweeping can be safely undertaken by putting down damp sawdust, to which the floor dust will adhere, or by using a vacuum cleaner. Spraying the floor with water before sweeping makes the air too moist, besides the risk of splashes or drops of water getting on the stacks of paper. Even under the strictest conditions there will be some dust, therefore a sheet of wrapping paper must be used to top each pile of paper or packages, and sheets of wrapping put on the floor for the stacks to stand on, the sides being tucked in all round to a height of 6 or 8 inches above the floor level. Wide avenues should be left between each double row of stacks, so that every stack can be reached without disturbing another. All those who have to handle the stock must have clean aprons or overalls and must keep their hands perfectly clean. It is surprising how many sheets a dirty thumb will spoil.

The stacks ought to be built up carefully so that there are no protruding sheets, which will certainly be broken at the edges when the paper is again lifted. The height of the stacks will depend on the size of the sheets. A small sheet will not stack safely to any great height, especially if it has a low finish, as a slight push may send it over. A safe rule is that no stack must be higher than a man of average height can build without the use of steps.

If the paper is in wrappers there is, of course, less danger of it being spoiled

in the stack. It is not advisable to use gas lighting in the stock rooms; apart from the risk of fire, the products of the combustion of gas have a deleterious effect on paper.

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CHAPTER XXI

WATER SUPPLY—RECOVERY AND RE-USE OF WATER

Water Supply.—A most important point to be considered when choosing a site for a paper-mill is undoubtedly that of water supply. Water is as important as transport facilities and the proximity of markets; unfortunately this has not always been taken into consideration when choosing a site, and some mills to-day are very hard put to it to find sufficient suitable water for their requirements.

The ideal water for all requirements of a modern mill is not commonly met with, and the mill is fortunate which can boast an adequate supply of water suitable for steam-raising and paper-making purposes.

In the first place it must be borne in mind that a very large quantity of water is required to produce a ton of paper, no matter of what quality. For the production of a rag paper 80,000 to 140,000 gallons of water are required per ton of paper, and a very large proportion of this is irrecoverable and runs to waste. For newsprint the amount varies from about 2000 gallons upwards, per ton.

The second point to be considered is the quality of the water, and in this connection the quality of the papers to be made will be the determining factor. If the water is very soft, such as water from peaty moors, it will suit the steam boilers, as it will eliminate both the necessity for providing a water-softening plant and all trouble with scale in the boilers and economisers.

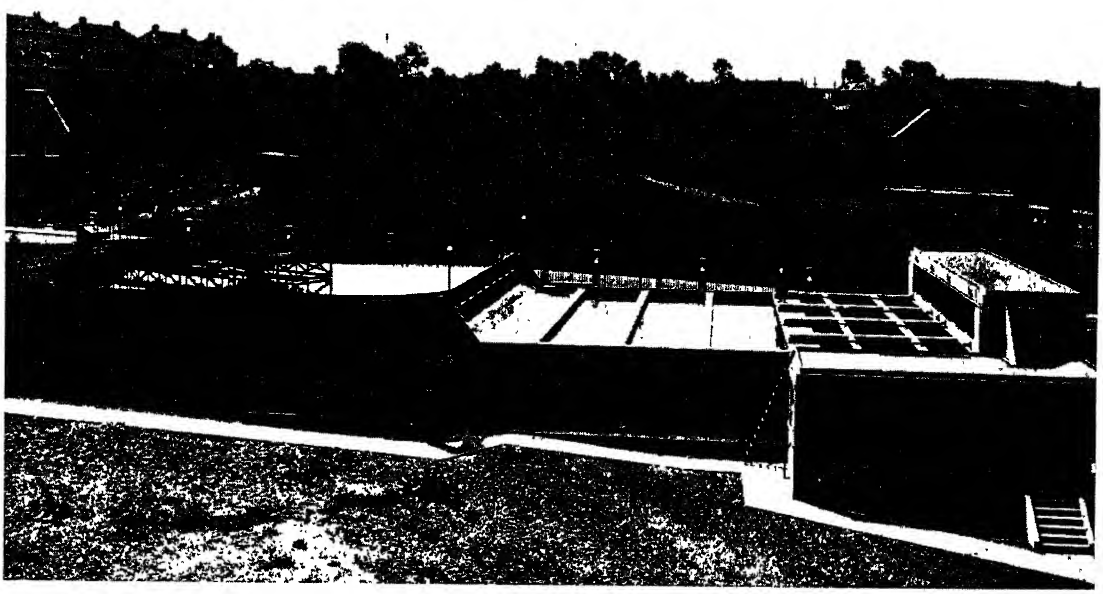
This water will, however, foul with slime and possibly with iron deposits many of the tanks and water-pipes in the mill, and, unless it is carefully filtered, with suspended matter.

Such water has many advantages, but it cannot be made to produce papers of such a pure and bright colour as other 'harder' waters, and it is usually necessary to pass it through a series of filters to remove the suspended matter and to improve the colour.

Where 'surface' water has to be used, unless the qualities of paper to be made are very low or highly coloured it will usually be found most satisfactory to filter it, as otherwise the colour of the paper will be at the mercy of the weather, and floods and other discolorations will have disastrous results at certain periods of the year.

Some of the filters at present available give excellent results, require little or no attention and are self-cleaning, this latter operation taking only a few minutes each day. They remove all suspended matter and make a wonderful improvement in the quality and brightness of the colour.

Brown peat water, often in flood time the colour of beer, comes through the filter quite clear and bright. The same applies to ordinary river water, which may often be contaminated with road water, surface water from streams, and in the summer months with rotting water-weeds.



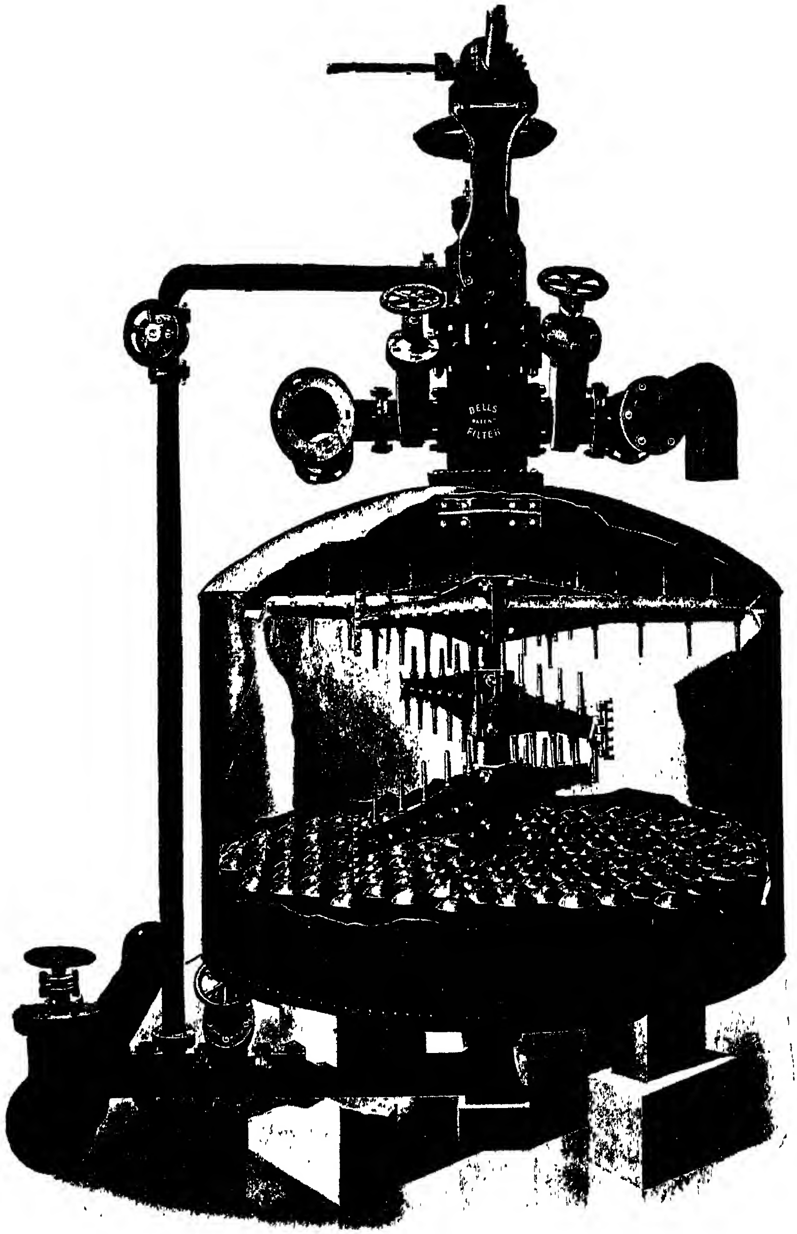
[*Paterson Engineering Co. Ltd.*

FIG. 148.—WATER CLARIFICATION AND FILTRATION PLANT AT A PAPER-MILL. CAPACITY 15 MILLION GALLONS PER DAY

A suitable type of filter for general paper-mill requirements is that known as the Bell filter (Fig. 149), which is working satisfactorily in many paper-mills at present. The Paterson Engineering Company also make a similar filter as shown in Fig. 150.

Hard waters containing calcium carbonate, calcium sulphate and magnesium salts, while very suitable for making paper, especially those qualities which have to be bright and clear both on the surface and especially in the look-through, have the great drawback of depositing scale in the pipes, economisers and steam boilers. If these waters are very hard, it is necessary to treat chemically that which is to be used for steam raising.

They may be used in their natural state for paper-making, but service pipes, etc., will frequently require to be scaled in order to keep them clean



[*Bell Bros., Manchester*

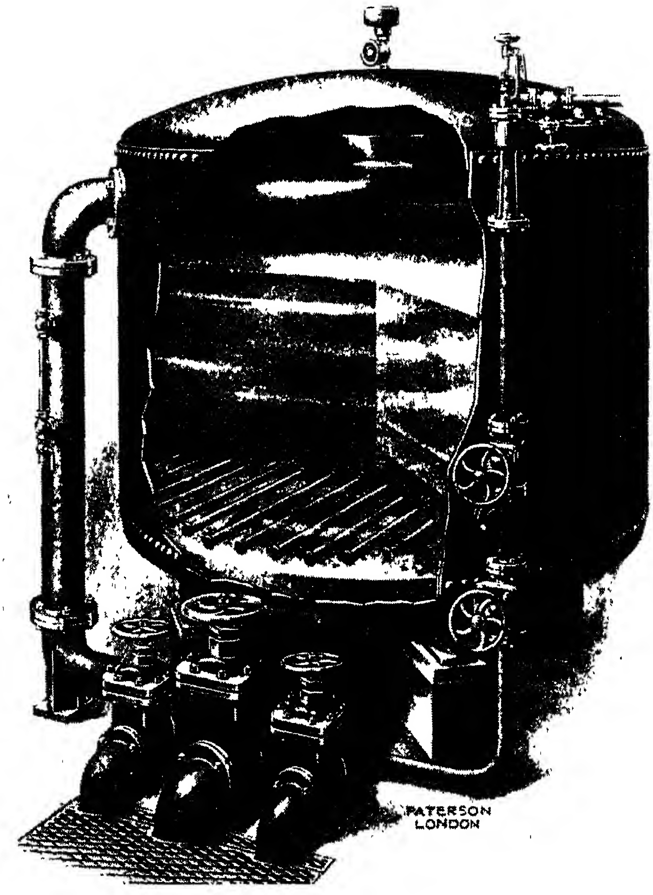
FIG. 149.—BELL PRESSURE FILTER

Internal view of the rotating arms and nozzles

and to prevent pieces of scale coming away into the stuff at the machine and thus spoiling the paper.

This trouble is most likely to occur if the pipes, etc., have been left empty for any length of time and have become dry.

When hard water has to be used for steam raising it must first be softened in order to prevent scale in the boilers and economiser pipes, and one of the plants in general use is that made by Paterson. The machine consists of a tower (Fig. 151), at the top of which is a mixing tank for chemicals and also the



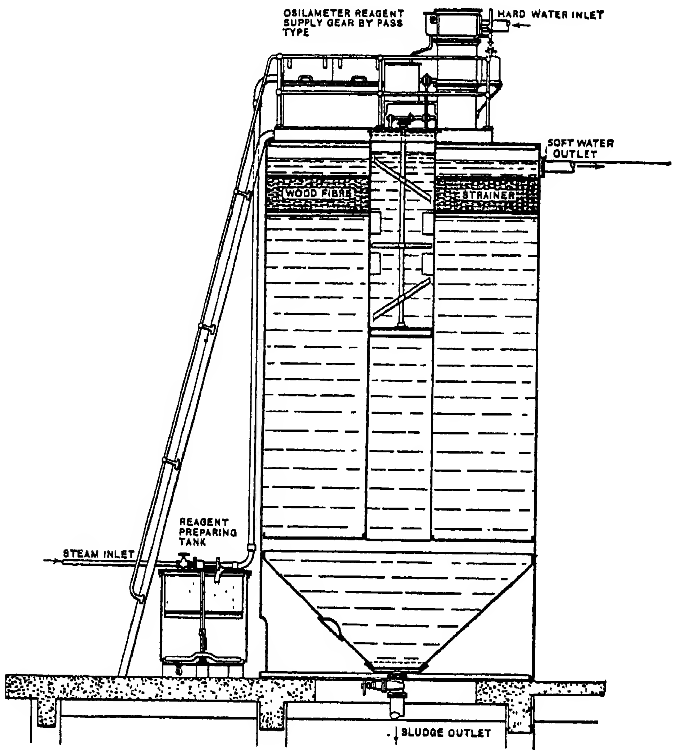
[*Paterson Engineering Co. Ltd.*

FIG. 150.—SECTION OF PRESSURE FILTER, SHOWING UNDER-DRAINING SYSTEM

intake for untreated water. The water flows down a central tube fixed in the middle of the tower, and is mixed with the softening chemicals as it passes down. When it reaches the bottom of the tube it passes up the tower again, depositing any heavy, insoluble matter at the bottom. On reaching the top it passes through a filter, where any suspended matter is removed, and is now softened and cleaned ready to pass to the boiler-feed tank, or any other place where it may be required. This system is effective and simple in operation and costs very little to run.

Surface water from springs and small streams or 'burns' may often be satisfactorily freed from suspended matter by passing it through a series of tanks filled with clean coke or sand. The water is made to flow upwards through the cone in the first tank and down through the coke in the second tank, and so on until it is sufficiently cleaned. The coke must, of course, be renewed periodically.

Another method is to fill the tanks first with drain-pipes and then with a



[*Paterson Engineering Co. Ltd.*

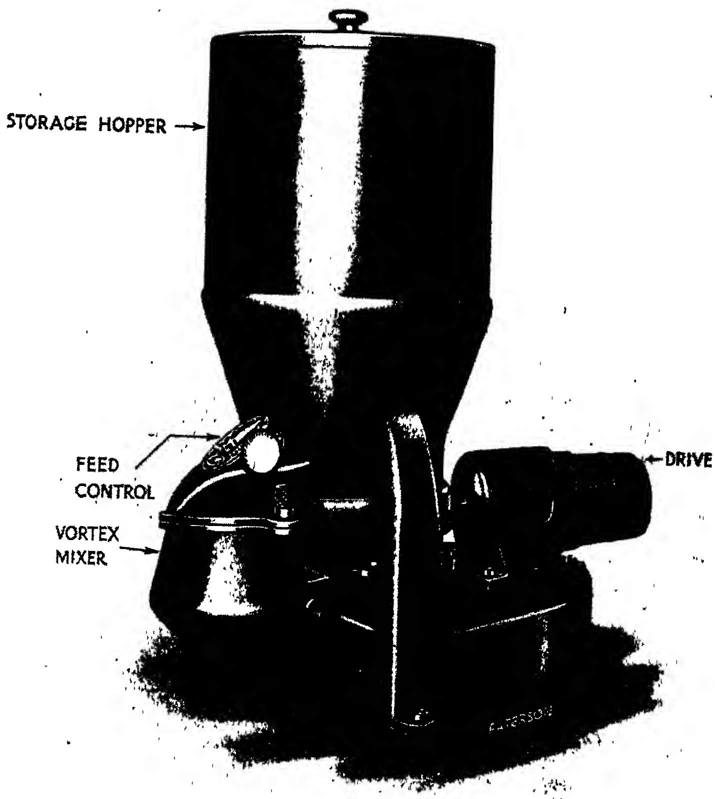
FIG. 151.—TYPICAL VERTICAL WATER SOFTENER, LIME-SODA TYPE

layer of coarse stones, then smaller stones, followed by a layer of gravel, and finally a layer of clean sand on top. In this way the water, passing through the various layers, deposits the suspended vegetable matter and slime, and finally appears at the top in a clean and clear state. The sand, etc., has to be removed frequently and washed in a washing machine, and is then put back in place ready to be used again.

These methods are both, of course, entirely mechanical, and no change takes place in the actual composition of the water. When a Bell filter is used the action may be partly chemical as well, as the water may come in contact with alum and so be softened and actually freed from colour by chemical action.

In choosing a site for a mill too much importance cannot be attached to the question of water supply, and exhaustive tests must be carried out to ascertain the amount and *quality* of the supply, having due regard to the immediate and possible future requirements.

In almost every mill vast quantities of water can, and should, be recovered for further use. This question is now receiving greater attention than formerly, and it is a most important one.



[*Paterson Engineering Co. Ltd.*

FIG. 152.—CHEMICAL DRY FEEDER, FOR THE ACCURATE ADDITION OF CHEMICALS FOR WATER TREATMENT

Broadly speaking, the water has to be recovered from the machine and returned to the beaters, or to the stuff box at the machine, but there are other places where a great deal can be recovered.

To take first a rag mill, which uses more water per ton of paper than other mills. Water is first used in the rag boilers; this is irrecoverable, owing to the presence of grease, soluble soaps, etc., and it must be passed to settling tanks if no convenient sewer is available. It should not in any case be returned to the river.

The rag washer uses a large amount of water, and this is not recovered, as it contains traces of the soaps formed in the boiler and also a quantity of rag fluff or fibres, but not sufficient to pollute a river. The rag breakers, where most of the washing is done, also use a very large quantity of water, and this is also not recovered, although if a wrapper machine is run at the mill some of it can certainly be used with advantage for furnishing the beaters.

There is a very large amount of rag fibre lost here, due to the finer fibres passing away through the meshes of the washing drums and the washer screens, and also through the button and sand catchers, where these are fitted. The loss sustained during this operation is serious and deserves more careful attention than it generally receives.

It might possibly pay to recover this fibre in a save-all, and some of the water used towards the end of the washing is quite clean enough to use again if water is scarce. This would necessitate the use of large tanks and a pump to return the water to the washer.

Immediately following the washing operation in the breaker comes the bleaching, and this uses more water; where the bleached stock is run into drainers or steeps the liquor from these latter should always be recovered, when rags are being bleached, and run into tanks, whence it may be pumped back to the potchers to start the next bleaching operation.

It is sometimes possible to use the spent liquor from three potchers to complete the bleaching of the rags in a fourth potcher without the addition of any fresh bleaching liquor, and this represents a great saving. This can only be done, however, when more than the necessary amount of bleach is being used in the first instance—*i.e.*, when hurrying stock through the mill.

The beaters are usually furnished with new unused water, owing to the fact that every care has to be taken to eliminate dirt, and to keep the shade of the paper bright and constant. This does not, of course, apply to low-grade papers, newsprint and printings, and even in the case of fine papers sufficient water should be available from the machine back-water system to furnish the beaters.

At the machine all spray water from the strainers, water from the save-alls beneath the wire and overflow water from the vacuum boxes should be collected and run to an auxiliary strainer or 'back knotter' and strained free from lumps, knots of fibres and rubber, and then pumped back to the stuff box for diluting the thick stuff from the stuff cock. The careful conservation of all this water represents an enormous saving in chemicals, such as engine size, alum, dyes, loading and small fibres. It also reduces the effluent, which must be disposed of ultimately. It also assists greatly in the reduction of froth and the prevention of scale in the water service system when hard waters are

used, and this operation has been proved, when carefully attended to, to double the length of life of the machine wire. In this case, formerly only about half the water required at the stuff box was recovered water, the other half being 'fresh' and very hard. It was found that after a week the machine wire was so filled up with a white limy deposit that it was necessary to remove it with a strong solution of vitriol. This, of course, ruined the wire in about 4 to 6 weeks, or even less.

When, however, use was made of all the water which could be recovered and no fresh water was added, no vitriol was required to clean the wires, and they lasted from 8 to 12 weeks without any special cleaning other than an occasional blow with the force jet.

It had also been found expedient to have a spray-pipe on all the wire rolls, whereas, after the back water only was used, no sprays were used except on the wash and breast rolls.

In mills making printings and newsprint there is no recoverable water except at the machines, and every drop of this should be carefully caught and returned to the beaters, stuff box and machine service system, either direct or after passing through some sort of save-all. This water is generally termed 'white water', and it comes from the wire and suction boxes at the machine. It is collected in the pit below the machine, and contains large quantities of clay and fibre from the deckle edges which are cut off, and also from the water which passes through the meshes of the wire, carrying clay and fibres with it.

The water is kept agitated by means of paddles in the pit, and is pumped to huge tanks above the breakers or beaters, whence it is run to the latter when furnishing.

There should be no dirty effluent at all from a news or printing mill, except floor washings, containing oil from bearings, etc., and the only fresh water which should usually be necessary will be for the sprays at the slices and guard board, for the spray damper at the reel end, and for the edge cutters.

Other mills making different grades of paper should be able to recover varying amounts of water, according to the conditions under which they work, and if it is found impossible to use all the water it should in any case be filtered to remove the valuable fibres and clay, which can be used again either in the same paper or in lower grades.

The Recovery and Re-use of Waste Waters, Fibrous Material and Loading

In almost all mills a large quantity of fibre and clay may be recovered from the back waters of the machines. Generally speaking, the lower the grade of paper being made the greater is the amount of stuff which can be recovered.

Until quite recently it was common practice for the waste waters containing size, colour, loading and fibres to be run to the drain, river or other convenient place, and thus much valuable material was lost and much pollution of rivers caused.

Two factors were chiefly responsible for the curtailment of these losses, one being the increased competition in the trade and consequent need for economical production, the second the tightening up of bye-laws concerning pollution by river conservators and fishery boards.

The yield of material in a rag mill may be taken to be from about 60 to 80 per cent, so that from 100 tons of rags anything from 20 to 40 tons are lost between the rag loft and the machine reel. A good deal of this loss is represented by unsuitable material thrown out, and also by the removal of dust, loadings, starch, grease and ligneous matter during the boiling and bleaching operations.

Apart from this, however, there is a serious loss of small fibres during the washing and draining of the stuff, and again at the machine, where a great deal of small fibrous material is washed away through the meshes of the machine wire. There is also a loss at the auxiliary strainer, due to hanks and knots of fibres which get caught here, which are so mixed with dirt, rubber, etc., as to be unfit for further use.

Stuff is also lost which runs down the wire when starting up, or if a break occurs there, and other small losses occur when starting and stopping by stuff going down the pit between the wet felt and second press, and between the second press and cylinder. These latter losses are very small, and may be prevented by the provision of clean wooden boxes to catch the stuff, provided that the stuff is carefully removed at frequent intervals and returned to the beaters in a clean state.

Where the mill makes nothing but fine qualities it will generally be found impossible to use again any of the fibres which may be recovered from the washing waters and the auxiliary strainer. The usual practice in dealing with such waste is to run it to tanks where the fibrous material may settle down, and the clear water is then run off to the river or drain. The tanks are periodically cleaned out and the stuff is thrown away as useless refuse.

If, however, the mill makes its own wrappers from time to time, or has a machine engaged in the manufacture of wrapping papers, it will pay to recover all this fibre in order to assist in making up the furnish of the wrapping papers. This is not only economical, but it also enables a really good wrapper to be made, on account of the rag fibres contained in the refuse.

The method employed to save this material is simple, and consists of running the waste washing water, overflow or cleanings from auxiliary strainers, waste from the wire pit and press pit into large tanks built up of perforated tiles. Here the water drains away, leaving a large proportion of the fibres lying in the bottom of the tank and round the sides. The tanks are periodically cleaned out and the stuff is taken up to the beaters to be furnished for wrappers. The tanks should be of a sufficiently large capacity to deal with all the water from the rag-washing engines, which contains only a small amount of fibre, and they must also be capable of dealing with the stuff from the machine wire pit when changing or washing up.

If this work is being properly and carefully carried out by the machineman the amount of effluent should not be excessive, but there will always be some waste from the bottom of the chest, the sand traps and strainers, and a small amount from the wire pit.

In mills making lower grades of paper the methods employed vary according to the general lay-out of the mill and the grades being manufactured, the amount of waste which has to be dealt with and the capacity of the mill to re-use this waste in lower-grade papers.

It may be taken as a general rule that most of the recovered stuff will have to be used in a paper of a lower grade, quality or colour from that which produced the waste water.

The most satisfactory method is as follows:

All water from the machine wire pit, press roll pits, wire save-alls and suction boxes should be collected in suitable tanks at the back side of the machine, whence it can be pumped back to any or all of the following places:

1. The machine back-water tank for supplying the mixing box.
2. The beater supply tanks.
3. The machine chests.
4. The sprays at the machine.

When the machine starts up, assuming the back-water service system to be empty, it will be necessary to use fresh water to dilute the stuff coming into the mixing box from the stuff tap, but as soon as the machine has started and the back water has had time to get round, the fresh water may

be shut off and no more will be required. There will thus be a supply of water, containing a little fibre, loading, size, alum and dye, in constant circulation at the machine. The surplus from the save-alls and wire pit over and above the requirements of the machine is then pumped up to large tanks situated above the beaters. From these tanks the beaterman draws his supply for furnishing and emptying the beaters, and for diluting stuff going through the refiners.

Re-use of Back Water.—When the web is being run down the wire for any length of time, such as that occupied in washing and turning a felt on a news machine, the stuff which collects in the pit is stirred up with water and pumped back direct to the machine chests. This obviates the necessity for shutting off the stuff and possibly upsetting the machine when it is running well.

There is a disadvantage in this method—namely, the dilution of the stock in the chest—and the machineman must be careful to see that when he starts up again his weight is not seriously affected.

The sprays at the strainers and on the wire rolls may be supplied with back water, withdrawn from the web at the suction boxes, and thus there is an economy in the use of fresh water and a consequent diminution in the quantity of back water to be dealt with subsequently.

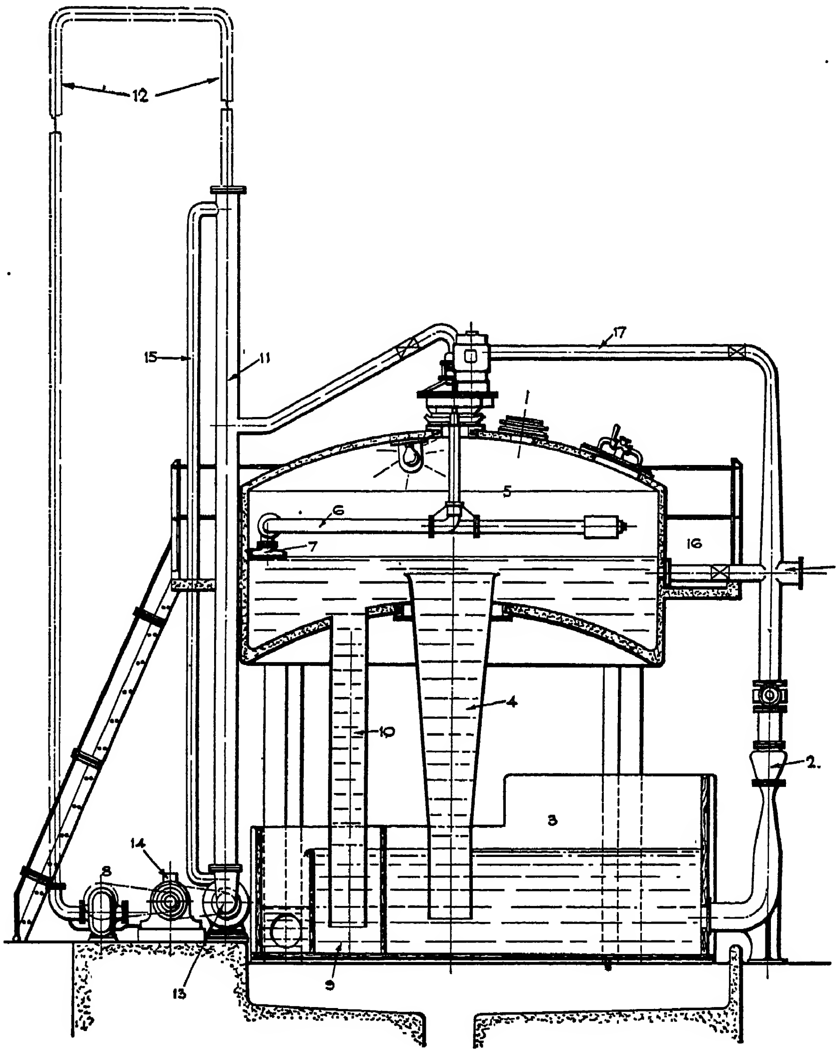
This water is drawn out at the boxes through the meshes of the wire and has consequently been well strained. It is then collected in a sump and forced by another pump at a high pressure to the strainer and other sprays about the machine.

When this method of supplying the sprays can be adopted the use of fresh water is cut down to a minimum, and it will then be necessary only to have a fresh-water spray on the breast roll, couch roll and possibly at the breast box to keep down froth.

Adka Save-all (Fig. 153).—This save-all employs the principle of flotation, as opposed to the older forms using the principle of sedimentation. The flotation is brought about by forcing the back water through a nozzle, designed on the lines of an injector, through which the air is drawn and intimately mixed with the back water. It is then passed into a chamber, and under vacuum the fibres, surrounded by minute bubbles of air, and flocculated by a suitable flocculating medium, rise to the top of the liquid, where they are drawn off by a scoop, and returned to the paper machine. The clarified water runs continuously from the bottom and is used whenever desired. A picture of the Adka is shown in Fig. 153.

The back water from the machine is passed through the main inlet (1) and travels down to the aerator nozzle (2), where air is drawn in through the air-

intake pipe and intimately mixed with the back water in the nozzle. It then passes to a wooden box (3); much froth is made in this box owing to the excess air escaping, and the air-intake pipe is led into this froth from a



[*Watford Engineering Works Ltd.*

FIG. 153.—THE ADKA PATENT SAVE-ALL

The cycle of operations is as follows:

The back water is pumped by pipe **1** through injector **2** to the tank **3** (the injector aerates the back water and by this means carried up any loading material contained in it).

From tank **3** the back water is drawn up pipe **4** to the main tank **5**. The fibres being aerated, plus the vacuum in tank **5**, causes the flow up pipe **4**.

The revolving pipe **6**, with its sucker **7**, is the suction pipe coupled to the vacuum pump **8**.

The thin layer of fibres floating upon the surface of the back water in tank **5** is sucked off by the sucker **7**. After being skimmed, the clarified water falls to discharge tank **9** by pipe **10**.

The air and recovered stock are drawn towards pipe **11**, the air ascending up the pipe **12** to the vacuum pump **8**. The recovered stock descends in barometric leg **11** to the centrifugal pump **13** and is pumped to the stuff chests or preferably the mixing box. Both pumps are driven by motor **14**. The compensating pipe **15** allows for a constant discharge from the centrifugal pump **13**.

Pipe **16** is to fill the tank when starting up; **17** reverses the flow of liquid for washing-out purposes.

Sight holes in cover with electric lamps allow for inspection of inside of tank **5**.

point above the aerator nozzle and keeps it from overflowing. The back water than flows upwards and back over another wooden partition to the base of the surge-pipe (4), up which it is drawn by the vacuum in the body of the Adka. This vacuum is maintained by the excess air being drawn off through the same rotating scoop (7), which deals with the thick stuff floating to the top. By reason of the vacuum in the chamber (5) the height of the floating stuff in the body is always maintained at the same level, since if the back water rises above the level of the inlet of the rotating scoop, no more air could be sucked from the body, and in consequence the back water could not rise any higher; and likewise if the back water should drop below the level of the scoop, the vacuum would be automatically increased, which would once more draw it up to the right height. In practice the level of the back water in the body seldom varies more than $\frac{1}{8}$ inch, which is usually insufficient to cause any serious fluctuation. The thick fibre and clay on the top of the back water in the body is drawn upwards to a separating chamber (11), where the stuff falls to the bottom and is dealt with by a centrifugal stuff pump (13), and the air rises to the top, where it is drawn off over a barometric column (12) by a drum vacuum pump which is always kept submerged by a priming tank set alongside (8). The centrifugal stuff pump should be of sufficient capacity to deal with the stuff drawn off, and be capable of pumping it to wherever desired, in most cases to the sand traps of the paper machine. The clarified water freed from the clay and fibre travels down a series of pipes (10) set around the base of the body, all flowing into one common outlet pipe into a box (9), from whence it is discharged to the drain or for re-use. The ends of the clarified water-pipe and the surge-pipe should always be completely submerged, otherwise the vacuum in the body will be broken and the whole procedure upset.

It will be readily understood that the time taken for the whole cycle of operations is very much shorter than that in a sedimentation type of save-all, as the back water is dealt with almost immediately, and it is only a matter of a few minutes to effect changes of colour. In practice, with short delivery pipes to the paper machine, 5 minutes is sufficient interval when changing to get the new colour to the paper machine.

The clarified water is practically free from fibres and clay, and may be used for all ordinary purposes in the mill.

SODA RECOVERY

ONE of the most expensive items in a paper mill using esparto, straw, or rags for its raw material is the caustic soda required for boiling. In small mills, using rags or rags and wood, the spent liquor from the boilers, both in quality and quantity, is not worth the expense of installing a recovery plant. The disposal of the liquor is a continual source of trouble with the River Pollution Authorities, yet it must be disposed of somehow, often at great expense.

When a mill is boiling esparto and using 3 to 4 cwt. of caustic soda per ton of grass, it becomes not so much a question of disposal as of recovery.

The principle of soda recovery is in itself very simple. The liquor from the boilers, containing the soda combined with the non-cellulose constituents of the raw material, is evaporated to a thick liquor and incinerated. The soda is thus converted into sodium carbonate, which is dissolved out from the incinerated mass and brought back to the caustic condition by the action of lime.

When the grass has been cooked, the steam is shut off and the vomiting action ceases as the pressure falls. The drain cock to the spent liquor reservoir is then opened and the liquor is discharged from the digester. A much better result is obtained by allowing slight pressure in the digester to express the liquid from the grass.

The cock is then shut and the boiler is filled, to above the level of the grass, with hot water obtained from the condensation of steam during the boil. Some steam is turned on to circulate the water through the pulpy mass. This wash is also run to the tank. A second wash may be carried out in the same way, but it is necessary to be careful here so that the liquor in the tank is not too much diluted for economical recovery of soda. After this, washing water may be run to the drain until the effluent is reasonably clear. A loss of soda occurs here of 2 to 5 per cent according to the efficiency of the first and second washes. The second wash may be pumped to a separate tank and used for the first wash of the next boil. Although this may reduce the work of the evaporators to some extent it is bad practice, chiefly because the colour of the grass is reduced, and any saving effected is nullified by the extra pumping and tanks required.

The liquor may be run through a drum washer on its way to the tank to keep back fibre and sludge, but here again a loss takes place and the liquor is more difficult to burn, requiring to be evaporated to a greater density. There is of course a risk of economiser tubes or other pipes becoming clogged up, but the regular cleaning and attention, which this department should receive if it is to be efficient, will reduce this to a minimum.

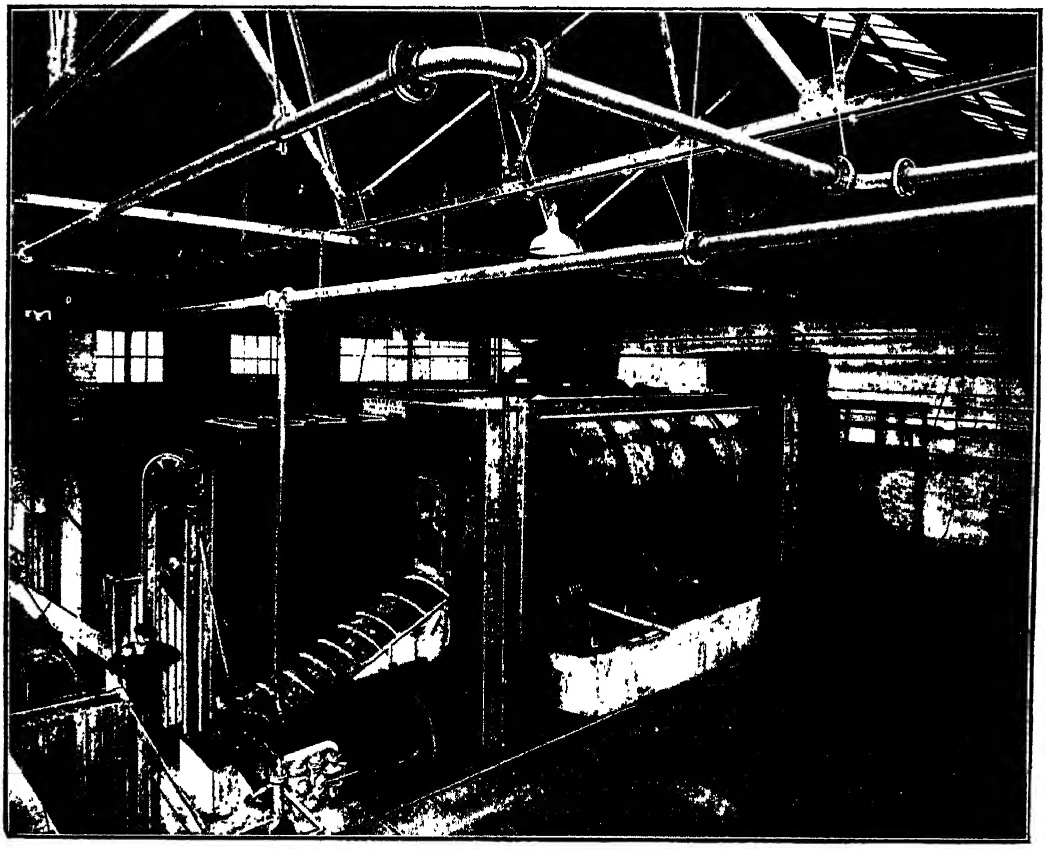
[*George Scott and Sons*

FIG. 154.—SCOTT QUADRUPLE EFFECT EVAPORATOR FOR CAUSTIC SODA LIQUOR

Evaporators are usually three in number, of which one is fed with steam from the main range. The plant is described as 'Triple Effect Vacuum Tube Evaporators'. Some plants have four evaporators and are described as Quadruple Effect (Fig. 154).

Advantage is taken of the lower boiling point induced by lessened atmospheric pressure, a vacuum being maintained by a barometric column and pump, or jet condenser. The steam created by the boiling liquor in one effect is used to bring it to a boil in the next, which is under less pressure. In some installations the liquor flows from the highest to the lowest temperature, in others the opposite way.

Each effect has three chambers, the bottom one being very shallow, the top one being much larger. The centre chamber is composed of a number of upright tubes connecting the top and the bottom, through which the liquor is agitated by means of the vacuum. The steam to assist the evaporation of this liquid is passed through the centre chamber, but on the outside of the tubes. The last effect or concentrator is constructed in the same manner as



[*George Scott and Sons*

FIG. 155.—TWO SCOTT ROTARY FURNACES WITH PATENT SODA GRATES

Nos. 1 and 2, but the steam for this concentrator is new steam, procured entirely from the main steam range. This ensures that the thickened liquor is passing to the furnace at the highest temperature, the drop in temperature being from the third to the first effect in this arrangement.

Where the drop in temperature is from the first to the third effect, the thickened liquor requires to be run to a steam-heated storage tank to increase its temperature, thereby making it more fluid and easy to burn.

The liquor has then been concentrated from about 4° Tw. to 60° Tw. (200° to 230° F.) by evaporation, and passes onwards to the rotary furnace (Fig. 155). This consists of a revolving firebrick-lined steel shell, whose internal diameter

increases towards the discharge end. It revolves about once per minute. Ignition of the liquor is caused in the first place by the flame from an auxiliary furnace with coal, oil, or wood at the start of a run, and with careful control the liquor will then remain alight throughout the run. In one type of furnace the liquor is sprayed in similarly to an oil-fired boiler.

Combustion is sustained by the burning of the organic matter brought forward with the liquor from the digesters.

[*George Scott and Sons*

FIG. 156.—CAUSTICISERS, AND IN REAR ROTARY VACUUM FILTER

There are several methods of subsequent treatment of the black ash. One method is to complete the combustion of all remaining carbon on a travelling chain grate over forced draught. Another consists in removing the ash from the furnace while combustion is still incomplete and spreading this ash over a perforated floor under which an air draught is induced. Complete combustion requires about two weeks under these conditions. This method has the disadvantage of requiring a long time and a good deal of floor area. The calcined ash, or 'black ash', is then soaked with boiling water, which absorbs

all the sodium carbonate, and this is drained to a pump through perforated tiles in the bottom of the soaking tank. This liquor is then pumped to a causticising pan (Fig. 156) with a half-round bottom and a mechanical

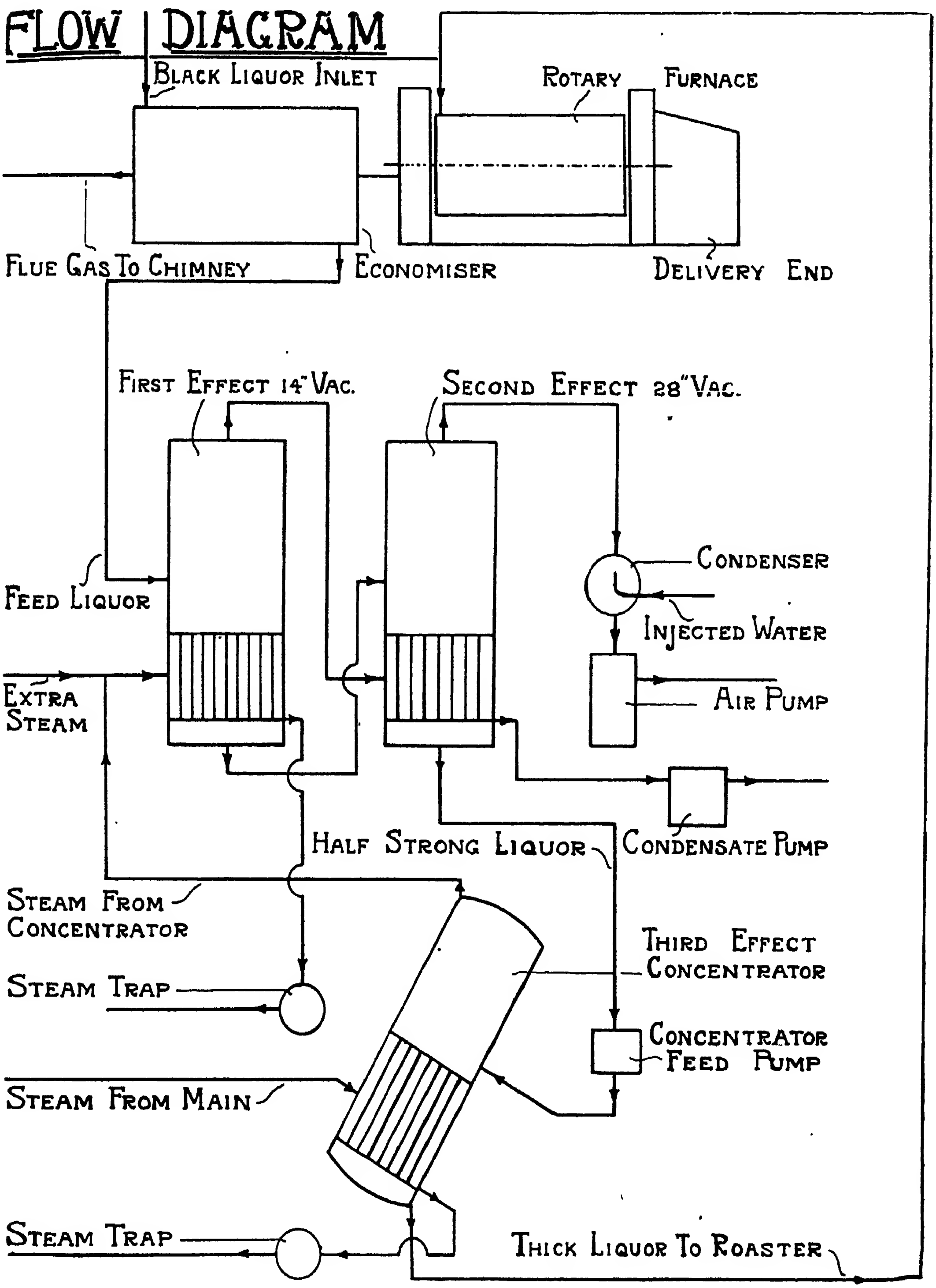


FIG. 157.—FLOW DIAGRAM OF CAUSTIC SODA RECOVERY PROCESS

agitator. A quantity of pure 'make-up' sodium carbonate is then added, with the necessary amount of lime, to the causticiser, where it is dissolved by boiling and agitation. The aim of the whole operation is to retain the maximum amount of sodium carbonate, any losses being replaced at the causticiser.

The required amount of lime is then added to the causticiser, the action being chemically designated so:

$$Na_2CO_3 + CaO + H_2O = CaCO_3 + 2NaOH$$

Up to 45 per cent of lime is required, and the whole is subsequently boiled for from 1 to 2 hours with direct steam and continuous agitation. Agitation then ceases and solids, principally chalk and carbon, are allowed to settle. 'Strong' liquor may then be drawn from the top of the causticiser. It is then recharged with water and agitated for a further hour. The solids are then again allowed to settle as before and a weaker liquor is drawn off. These two batches are then mixed and give a batch of boiling liquor at somewhere about 14° Tw. The causticiser is again filled with water and agitated as before, and when all solids have settled out the resulting liquor is drawn off and serves as a 'water' for the next 'weak' liquor production.

The losses, which are inevitable, result from carrying off sodium carbonate in the digested grass, in the sludge from the drum washer, if used, in the vapour from the evaporating plant, by particle entrainment in the rotary furnace flue gases, and incomplete recovery from the black ash, and sludge from the causticiser pans.

The sludge left in the causticiser pan is a very difficult problem. It may be drawn off and settled in ponds, the liquor from the surface being run away and the sludge being dug out and deposited in some waste ground. It can be readily understood that there may be many difficulties in this proceeding, as it is not easy to find sufficient waste ground to dispose of the sludge from a large mill.

It is possible, however, to dry this sludge and recondition it so that it may be used as lime for agricultural purposes.

The recovery of from 70 to 80 per cent is possible economically, and higher recoveries than this have been claimed. Although it is theoretically possible to recover nearly 100 per cent of the original soda used, the expense would be greater than the value of the recovered soda. Where there is no easy method of disposing of sludge and extra washings of the grass owing to the proximity of a preserved river, recovery has to be of the utmost possible quantity in order to satisfy River Authorities. In this case extra expense is of course inevitable and unavoidable.

APPENDIX OF TABLES

MOISTURE IN PAPER ON MACHINES

THE following tables show the percentage of moisture contained in the web from the breast box to the finishing house, and also the proportion of water to dry fibre.

FOURDRINIER.

Class of Paper	*White News*		*Common News*	
Substance in D.C. 500's	25 lb.		21½ lb.	
Speed	580 ft.		590 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	98.92	91.6	99.2	124.0
Couch	77.6	3.46	78.1	3.57
First press	73.1	2.59	75.5	3.08
Second press	69.3	2.25	71.6	2.52
Third press	68.4	2.16	71.6	2.52
Middle cylinder	41.1	0.69	49.1	0.96
Machine calenders	6.2	0.06	7.0	0.08
After damping	12.2	0.14	9.4	0.10
After super-calender	7.2	0.08	8.8	0.10

Length of machine wire, 70 feet. Six suction boxes. First press, maple; second press, granite; third press, brass. All on rubber. Thirty 5 feet 6 inch drying cylinders. Cooling roll at reeling drum. Spray damper before reeling drum.

FOURDRINIER

Class of Paper	*Mechanical Printing*		*Antique Wove Printing*	
Substance in D.C. 500's	21½ lb.		68 lb.	
Speed	330 ft.		140 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	99.0	99.0	97.8	44.4
Couch	85.1	5.71	80.0	4.00
First press	69.6	2.29	63.4	1.73
Second press	64.9	1.85	61.4	1.59
Intermediate rolls	—	—	17.3	0.21
Machine calenders	6.2	0.07	4.8	0.05
After damping	10.6	0.12	—	—
After super-calender	8.2	0.09	—	—
After cutting and finishing	—	—	5.2	0.05

This machine had a wire 50 feet long, and iron first and second top press rolls, with rubber bottom rolls.. There were twenty-two 5-feet drying cylinders.

FOURDRINIER

Class of Paper	*Tissue*	
Substance in D.C. 500's	9.17 lb.	
Speed	350 ft.	
	%	*Parts water per part fibre.*
Breast box	99.52	207.0
Couch	84.3	5.37
First press	70.2	2.35
Second press	68.5	2.17
Middle cylinder	47.3	0.90
Reel	4.5	0.05

M.G. MACHINE

Class of Paper	*Pure Sulphide*		*'Manilla' Envelope Paper*	
Substance in D.C. 500's	16 lb.		32 lb.	
Speed	150 ft.		140 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	99.4	165.7	98.8	82.3
Couch	85.0	5.67	81.4	4.38
First press	68.3	2.16	69.9	2.32
Before M.G. cylinder	65.6	1.91	68.0	2.13
At reel	5.6	0.06	5.6	0.06

M.G. MACHINE

Class of Paper	*Pressing or Cover Paper*		*Sulphite Litho*	
Substance in D.C. 500's	47½ lb.		32½ lb.	
Speed	91 ft.		100 ft.	
	%	*Parts water per part fibre*	%	*Parts water per part fibre*
Breast box	98.6	70.4	99.0	99.0
Couch	78.5	3.65	73.9	2.83
First press	67.1	2.04	58.3	1.40
Before M.G. cylinder	60.9	1.56	—	—
At reel	3.4	0.04	4.4	0.05

MOISTURE REMOVED BY THE COUCH ROLLS

It is sometimes asserted that the couch rolls do not remove any appreciable amount of water from the web. This is not so. The result of several tests showed that about 10 per cent of water is removed, or the proportion of water to fibre is almost halved.

Moisture in web before couch roll 86.85 per cent, or 6.60 parts water per part fibre.

Moisture in web after couch roll 78.64 per cent, or 3.68 parts water per part fibre.

The moisture content is estimated on the wet pulp weight.

The paper was pure sulphite and the substance 24½ lb. demy.

Colour Reactions of Fibres by Common Stains

Fibre	*Iodine and Zinc Chloride*	*Iodine and Sulphuric Acid*	*Aniline Sulphate*	*Phloro-glucinol*
Cotton	Violet	Blue	—	—
Flax	Violet	Blue	—	—
Hemp	Violet	Blue	Pale yellow	Violet red
Jute	Brown yellow	Green blue	Golden yellow	Deep red
Ramie	Dull violet	Dull blue	—	—
Manilla hemp	Yellow to violet	—	Yellow	Red
New Zealand flax	Golden yellow	Green blue	Yellowish	Pale red
Chemical wood	Blue violet	Blue to grey	Pale yellow	Pale red
Mechanical wood	Yellow	Dark yellow	Dark yellow	Deep red

Iodine and Zinc Chloride (Herzberg Stain). Dissolve 20 grms. zinc chloride in 10 ml. water and add to a solution of 2.1 grms. potassium iodide and 0.1 grm. iodine in 5 ml. water. Allow to stand for 24 hours and decant the clear solution, and finally add a crystal of iodine to the clear solution. Place a drop of the solution on the disintegrated and teased fibres and mop up the excess stain to avoid too deep a colouration.

Iodine and Sulphuric Acid. Dissolve 2.85 grms. iodine and 5.0 grms. potassium iodide in 100 ml. water. Add 5 ml. glycerine.

Spot the fibre mass with the iodine solution, mop up the excess stain after standing two minutes, and add a spot of sulphuric acid solution (70 ml. concentrated sulphuric acid added to 30 ml. water).

Aniline Sulphate. Dissolve 1 grm. aniline sulphate in 50 ml. water and apply solution as with iodine stains.

Phloroglucinol. Dissolve 1 grm. phloroglucinol hydrochloride in 50 ml. ethyl alcohol and add 25 ml. concentrated hydrochloric acid. Apply the stain as with iodine stains.

PAPER TRADE CUSTOMS

CODIFIED AND ADOPTED BY THE PAPER-MAKERS' ASSOCIATION OF GREAT BRITAIN AND IRELAND (INCORPORATED); THE NATIONAL ASSOCIATION OF WHOLESALE STATIONERS AND PAPER MERCHANTS; THE EMPLOYERS' FEDERATION OF ENVELOPE MAKERS AND MANUFACTURING STATIONERS; AND THE UNITED KINGDOM PAPER BAG MANUFACTURERS' ASSOCIATION

Group Reference Letters.—A: Cloth-lined Papers, Coated Art Papers and Enamels, Copyings, Tissues, Drawing Cartridges, Drawing Papers, Blottings, Dryings, Filterings, Duplicators, Foils, Gum Papers, Insulating Papers, Machine Writings and Printings, Pulp Boards, Tracing Papers, Envelope Papers, Manillas for other than wrapping purposes, Caps for other than wrapping purposes, and similar papers. *B:* Cards, Pasteboards, Glazed Pressing Boards, Greaseproof, Imitation Parchment, News, Waterproof Papers, Waxed, and similar papers. *C:* Box Boards, Browns, Corrugated Straw, Leather Boards, Middles, Mill Boards, Mill Wrappers, Sugars, Casings, Krafts, Sealings, Wrappings, Cartridges, and similar papers.

Conditions of Sale.—Prices may be agreed: (1) By weight, whether put up in reams, reels, or any other form. (2) Per ream, based upon nominal weight.

Terms and Delivery.—(1) Quotations are understood to be net and carriage paid to buyer's address. Goods invoiced and despatched up to and including 25th of the month shall be paid for during the following month, provided delivery has been effected by date when payment is due. (2) Delivery in the British Isles shall include delivery at buyer's warehouse or that of his consignee.

Packing and Marking.—Boards, Frames, Cases, and Special (not ordinary cardboard) Centres shall be chargeable at reasonable rates, to be refunded in full when returned within a reasonable time, carriage paid and in good condition. The outside of the wrapper of each ream shall be marked with the nominal weight, except in cases where the weight charged is above nominal.

Machine-Made Writings, Printings, etc.—A ream contains 500 sheets. Reams are graded as 'Good', 'Retree' and 'Broke'. 'Retree' is subject to 10 per cent reduction. 'Broke' is subject to 20 per cent reduction. All fine papers under 15 lb. Large Post 500's shall be classed as 'Bank'.

Wrappings, Caps, etc.—A ream contains 480 sheets.

Hand-Made Papers.—A 'Mill' ream 'Good' or 'Retree' contains 472 sheets, consisting of 18 'Inside' quires of 24 sheets each and 2 'Outside' quires of 20 sheets each. The 'Outside' quires are placed one at the top and one at the bottom of the ream. An inside ream 'Good' or 'Retree' contains 480 sheets, made up of 20 'Inside' quires of 24 sheets each. 'Retree' is subject to 10 per cent reduction, and 'Broke' to 50 per cent reduction.

Wrappers.—The chargeable weight shall include weight of necessary Ream and Reel Wrappers (not Bale Wrappers), String and Centres (excepting those of wood or metal).

Substance Variations.—Average variation shall not exceed 5 per cent either way. Group 'A': Nominal weight of sheets and reels shall be chargeable if actual weight exceeds or is not more than 2½ per cent under nominal weight. Actual weight shall be chargeable if more than 2½ per cent under nominal weight. Group 'B': Actual weight of sheets and reels shall be chargeable up to 2½ per cent in excess of nominal. Group 'C': Actual weight of sheets and reels shall be chargeable provided average variation does not exceed 5 per cent either way.

Short Yardage.—Claims for short yardage can only be based upon result obtained from yardage measurements.

Measurement Variations.—(1) Width of reels shall not vary more than ½ per cent, with a maximum permissible variation of ¼ inch. (2) The variation in measurement of paper in sheets must not exceed ½ per cent either way above or below the ordered measurement, provided always that where ½ per cent is greater than ¼ inch the permissible variation shall be ¼ inch, and that where ½ per cent is less than ⅛ inch the permissible variation shall be ⅛ inch.

Special Makings.—For makings of Groups 'A', 'B' and 'C' of special size, substance, tint, water-mark, etc., an order shall be deemed to be properly filled if the quantity supplied is within the following limits either way of the quantity ordered: 1 ton or less, 12½ per cent; above 1 ton and not exceeding 5 tons, 7½ per cent; above 5 tons, 5 per cent; not applicable to hand and mould mades. Any excess beyond such limits shall be cut down to the nearest standard size and taken by the buyer at the proportionate price of such size.

Materials.—Unless it is otherwise expressly stipulated in the order, the paper-maker shall be free to use his discretion in the selection of materials.

Dandy Rolls and Moulds.—Buyers requiring a special water-mark shall provide the roll or moulds free of charge to the paper-maker.

Deliveries.—Deliveries may be suspended in the event of: (1) Any contingency arising beyond the control of the buyer or seller, such as war, fire, drought, interruption of transport, impediment to navigation through ice, strikes, lock-outs, and the like. (2) Any accident and/or partial damage during such time as may be required to make good such accident and/or damage. The buyer or seller, as the case may be, shall give prompt notice to the other party of the cause and commencement of such suspension, and in like manner when it ceases. In such cases deliveries shall be resumed as soon as is practicable, and where they form part of a contract spread over periods of time, they shall be resumed at the same rate as provided for in the

contract. In the event of the works of the buyer or seller being totally destroyed, and not rebuilt or replaced within twelve months, the contract shall be considered null and void. In the case of contracts for delivery in instalments, each delivery shall be considered a separate contract.

Delayed Deliveries.—(1) Specification of makings shall be sent to the seller in reasonable time for delivery on due date. If the paper contracted for be ready for delivery on the specified date, and the buyer does not take delivery when requested by the seller to do so, it shall be invoiced forthwith and invoice taken to account. If the whole of the delivery be not ready, the seller shall not be entitled to invoice any portion. (2) Paper stored at mill shall be subject to a rent charge of 6d. per ton per week for any period it lies at mill after 14 days from date of invoice, except in cases where delay is due to causes beyond buyer's control. Maximum period for storing at mill shall be 3 months.

Complaints of Quality, etc.—Claims for defective quality, short, weight etc., shall be made in writing within 14 days after delivery, but this is not to operate in cases where defective quality cannot reveal itself during this period. Such protection shall not be given beyond 3 months. In cases where delivery is within the British Isles, at least half the parcel must be available for examination. For export business, six representative outturn sheets shall be supplied with invoice, but the English exporter is entitled to return to the question of quality in cases where his export buyer subsequently reports any defect not revealed by outturn sheets.

Contracting Out.—Any or all of these terms may be varied or made inapplicable by the terms of the contract or order.

Arbitration.—(1) All disputes arising under any contract or order shall be submitted to arbitration in the United Kingdom. (2) Each party shall appoint his arbiter, and the arbiters shall choose their umpire before proceeding. If the dispute relates to quality, the arbiters and umpire must be experts in paper, and they shall decide whether the paper complained of is a fair commercial match of quality to be supplied. Should they decide that it is not, they may authorise rejection, or they may order acceptance subject to stated allowance, in which latter case they shall state whether the allowance shall apply to all or part of such portion as has been used before their examination, and their decision shall be final and binding on both parties. Should either side fail to appoint his arbiter within the prescribed 14 days, the arbiter appointed by the other party shall act for both, and his award shall be binding on both parties as though he had been appointed with their joint consent. The costs of such reference shall be borne as the arbiters and umpire decide.

Note.—The trade customs as codified in January, 1906, are hereby cancelled.

Equivalent Weights of Printing Papers expressed in Terms of Lbs. 480's

Large Post (16½×21)	11	12	14	15	16	17	18	19	20	21	22
Foolscap (16½×13¼)	7	7⅝	8⅞	9½	10⅛	10¾	11⅜	12	12⅝	13¼	14
Pinched Post (18½×14¾)	8¾	9½	11⅛	11¾	12⅝	13½	14¼	15	15¾	16⅝	17⅜
Post (19×15¼)	9¼	10⅛	11¾	12⅝	13½	14¼	15⅛	16	16¾	17⅝	18½
Demy (20×15½)	9⅞	10¾	12⅝	13½	14⅜	15¼	16⅛	17	18	18⅞	19¾
Medium (22×17½)	12¼	13⅜	15⅝	16¾	17⅞	19	20	21⅛	22¼	23⅜	24½
Royal (24×19)	14½	15⅞	18½	19¾	21⅛	22⅜	23¾	25⅛	26⅜	27¾	29
Super Royal (27×19)	16⅜	17⅞	20¾	22¼	23¾	25¼	26¾	28¼	29⅝	31⅛	32⅝
Imperial (30×22)	21	22⅞	26¾	28⅝	30½	32½	34⅜	36¼	38⅛	40	42
Sheet and ⅓ Foolscap (22×13½)	9½	10⅜	12	12⅞	13¾	14⅝	15½	16⅜	17¼	18	18⅞
Sheet and ½ Foolscap (24¾×13¼)	10½	11½	13⅜	14⅜	15⅜	16¼	17¼	18¼	19⅛	20⅛	21
Double Foolscap (26½×16½)	14	15¼	17¾	19	20¼	21½	22¾	24	25¼	26½	27⅞
Double Large Post (33×21)	22	24	28	30	32	34	36	38	40	42	44
Double Demy (31×20)	19¾	21½	25⅛	26⅞	28¾	30½	32¼	34	35⅞	37⅝	39⅜

Large Post (16½×21)	23	24	25	26	27	28	29	30	31	32	33	34	35
Foolscap (16½×13¼)	14⅝	15¼	15⅞	16½	17⅛	17¾	18⅜	19	19⅝	20¼	20⅞	21½	22⅛
Pinched Post (18½×14¾)	18⅛	19	19¾	20½	21⅜	22⅛	22⅞	23⅝	24½	25¼	26	26⅞	27⅝
Post (19×15¼)	19¼	20⅛	21	21¾	22⅝	23½	24¼	25⅛	26	26⅞	27⅝	28½	29⅜
Demy (20×15½)	20⅝	21½	22⅜	23⅜	24¼	25⅛	26	26⅞	27¾	28¾	29⅝	30½	31⅜
Medium (22×17½)	25⅝	26¾	27⅞	29	30	31⅛	32¼	33⅜	34½	35⅝	36¾	37⅞	39
Royal (24×19)	30⅜	31⅝	33	34¼	35⅝	36⅞	38¼	39½	40⅞	42⅛	43½	44¾	46⅛
Super Royal (27×19)	34⅛	35⅝	37⅛	38½	40	41½	43	44½	46	47½	48⅞	50⅜	51⅞
Imperial (30×22)	43⅞	45¾	47⅝	49⅝	51½	53⅜	55¼	57¼	59⅛	61	62⅞	64⅞	66¾
Sheet and ⅓ Foolscap (22×13½)	19¾	20⅝	21½	22⅜	23¼	24	24⅞	25¾	26⅝	27½	28⅜	29¼	30
Sheet and ½ Foolscap (24¾×13¼)	22	23	23⅞	24⅞	25⅞	26¾	27¾	28¾	29⅝	30⅝	31½	32½	33½
Double Foolscap (26½×16½)	29⅛	30⅜	31⅝	32⅞	34⅛	35⅜	36⅝	37⅞	39⅛	40½	41¾	43	44¼
Double Large Post (33×21)	46	48	50	52	54	56	58	60	62	64	66	68	70
Double Demy (31×20)	41	43	44¾	46⅝	48⅜	50⅛	52	53¾	55½	57⅜	59⅛	60⅞	62¾

Equivalent Weights of Writing Papers expressed in Terms of Lbs. 480's

Demy (22½×17½)	11	13	14	15	16	17	18	19	20	21	22
Large Post (21×16½)	9¾	11½	12⅜	13¼	14⅛	15	15⅞	16¾	17⅝	18½	19⅜
Medium (18×23)	11⅝	13¾	14¾	15⅞	16⅞	17⅞	19	20	21⅛	22⅛	23¼
Royal (25×20)	14	16⅝	17⅞	19⅛	20⅜	21⅝	22⅞	24¼	25½	26¾	28
Super Royal (27½×20)	15⅞	18⅝	20⅛	21½	23	24⅜	25⅞	27¼	28¾	30⅛	31⅝
Imperial (22×30)	18½	21⅞	23½	25¼	26⅞	28½	30¼	31⅞	33⅝	35¼	36⅞
Double Foolscap (27×17)	12⅞	15¼	16⅜	17½	18⅝	19⅞	21	22⅛	23⅜	24½	25⅝
Sheet and ½ Post (23½×19½)	12⅞	15¼	16⅜	17½	18¾	19⅞	21	22⅛	23⅜	24½	25⅝
Double Crown (30×20)	16⅞	19⅞	21⅜	22⅞	24½	26	27½	29	30½	32	33⅝
Double Large Post (33×21)	19⅜	23	24¾	26½	28¼	30	31¾	33½	35¼	37	38¾
Double Demy (35×22½)	22	26	28	30	32	34	36	38	40	42	44
Double Royal (40×25)	28	33⅛	35⅝	38⅛	40¾	43¼	45¾	48⅜	50⅞	53⅜	56
Quad Crown (40×30)	33⅝	39⅝	42¾	45¾	48⅞	51⅞	54⅞	58	61	64	67⅛

Demy (22½×17½)	23	24	25	26	27	28	30	32	34	36	38	40
Large Post (21×16½)	20¼	21⅛	22	23	23⅞	24¾	26½	28¼	30	31¾	33½	35¼
Medium (18×23)	24¼	25¼	26⅜	27⅜	28½	29½	31⅝	33¾	35¾	37⅞	40	42⅛
Royal (25×20)	29¼	30½	31¾	33⅛	34¾	35⅝	38⅛	40¾	43¼	45¾	48⅜	50⅞
Super Royal (27½×20)	33	34⅜	35⅞	37¼	38¾	40⅛	43	45⅞	48¾	51⅝	54½	57⅜
Imperial (22×30)	38⅝	40¼	42	43⅝	45⅜	47	50⅜	53¾	57	60⅜	63¾	67½
Double Foolscap (27×17)	26⅞	28	29⅛	30⅜	31½	32⅝	35	37¼	39⅝	42	44¼	46⅝
Sheet and ½ Post (23½×19½)	26⅞	28	29⅛	30⅜	31½	32⅝	35	37¼	39⅝	42	44¼	46⅝
Double Crown (30×20)	35⅛	36⅝	38⅛	39⅝	41¼	42¾	45¾	48⅞	51⅞	54⅞	58	61
Double Large Post (33×21)	40½	42½	44	45⅞	47⅝	49⅜	52⅞	56⅜	59⅞	63⅜	67	70½
Double Demy (35×22½)	46	48	50	52	54	56	60	64	68	72	76	80
Double Royal (40×25)	58½	61	63½	66⅛	68⅝	71⅛	76¼	81⅜	86⅜	91½	96⅝	101⅝
Quad Crown (40×30)	70⅛	73¼	76¼	79¼	82⅜	85⅜	91½	97⅝	103⅝	109¾	115⅞	122

SUBSTANCE EQUIVALENTS: GRAMMES AND POUNDS.

Grammes per Square Metre	*Demy* (22½ × 17½)			*Royal* (25 × 20)			*Double Foolscap* (27 × 17)			*Double Crown* (30 × 20)		
	480's *Lb.*	500's *Lb.*	516's *Lb.*	480's *Lb.*	500's *Lb.*	516's *Lb.*	480's *Lb.*	500's *Lb.*	516's *Lb.*	480's *Lb.*	500's *Lb.*	516's *Lb.*
20	5.38	5.6	5.78	6.82	7.1	7.33	6.26	6.52	6.73	8.19	8.53	8.8
21	5.64	5.88	6.06	7.16	7.46	7.7	6.57	6.84	7.06	8.6	8.96	9.24
22	5.91	6.16	6.35	7.5	7.81	8.06	6.89	7.17	7.4	9.01	9.39	9.68
23	6.18	6.44	6.64	7.84	8.16	8.43	7.2	7.5	7.74	9.42	9.81	10.13
24	6.45	6.73	6.93	8.18	8.52	8.79	7.51	7.82	8.07	9.83	10.24	10.57
25	**6.72**	**7.0**	**7.22**	**8.52**	**8.87**	**9.16**	**7 82**	**8.15**	**8.41**	**10.24**	**10.67**	**11.01**
26	6.99	7.28	7 51	8.87	9.23	9.53	8.14	8.48	8.75	10.65	11.09	11.45
27	7.26	7.56	7.8	9.21	9.59	9.9	8.45	8.8	9.08	11.06	11.52	11.89
28	7.53	7.84	8.09	9.55	9.95	10.27	8.76	9.12	9.42	11.47	11.95	12.23
29	7.8	8.12	8.38	9.89	10.3	10.63	9.08	9.45	9.76	11.88	12.38	12.77
30	**8 06**	**8.4**	**8.66**	**10.23**	**10 66**	**11.0**	**9.39**	**9.78**	**10.09**	**12.29**	**12.8**	**13.21**
31	8.33	8.68	8.95	10.57	11.01	11.36	9.7	10.1	10.43	12.7	13.23	13.65
32	8.6	8.96	9.24	10.91	11.36	11.73	10.02	10.43	10.77	13.11	13.66	14.09
33	8.87	9.24	9.53	11.25	11.71	12.09	10.33	10.76	11.1	13.52	14.08	14.53
34	9.14	9.52	9.82	11.59	12.07	12.46	10.64	11.08	11.44	13.93	14.51	14.97
35	**9.41**	**9.8**	**10.11**	**11.93**	**12.43**	**12.83**	**10.95**	**11.41**	**11.77**	**14.34**	**14.93**	**15.42**
36	9.68	10.08	10.41	12.28	12.79	13.2	11.27	11.74	12.11	14.75	15.36	15.86
37	9.95	10.36	10.7	12.62	13.15	13.57	11.58	12.06	12.45	15.16	15.79	16.3
38	10.21	10.64	10.98	12.96	13.5	13.93	11.89	12.39	12.78	15.57	16.22	16.74
39	10.48	10.92	11.27	13.3	13.85	14.29	12.21	12.72	13.12	15.98	16.64	17.18
40	**10.75**	**11.2**	**11 56**	**13 64**	**14 21**	**14.66**	**12.52**	**13.04**	**13.46**	**16.38**	**17.06**	**17.61**
41	11.02	11.48	11.85	13.98	14.56	15.02	12.83	13.37	13.79	16.79	17.49	18.05
42	11.29	11.76	12.14	14.32	14.91	15.39	13.15	13.7	14.13	17.2	17.92	18.49
43	11.56	12.04	12.43	14.66	15.27	15.76	13.46	14.02	14.47	17.61	18.34	18.93
44	11.83	12.32	12.72	15.0	15.62	16.12	13.77	14.34	14.8	18.02	18.77	19.37
45	**12.1**	**12.6**	**13.01**	**15.34**	**15.98**	**16.49**	**14.08**	**14.67**	**15.14**	**18.43**	**19.2**	**19.81**
46	12.36	12.88	13.29	15.69	16.34	16.86	14.4	15.0	15.48	18.84	19.62	20.25
47	12.63	13.16	13.58	16.03	16.7	17.23	14.71	15.32	15.81	19.25	20.05	20.69
48	12.9	13.44	13.87	16.37	17.06	17.6	15.02	15.65	16.15	19.66	20.48	21.13
49	13.17	13.72	14.16	16.71	17.41	17.96	15.34	15.97	16.49	20.07	20.91	21.57
50	**13.44**	**14.0**	**14.45**	**17.05**	**17.76**	**18.33**	**15.65**	**16.3**	**16.82**	**20.48**	**21.33**	**22.02**
60	16.12	16.8	17.33	20.46	21.3	21.99	18.78	19.56	20.18	24.58	25.6	26.42
70	18.88	19.6	20.22	23.86	24.85	25.66	21.9	22.81	23.54	28.68	29.87	30.83
80	21.5	22.4	23.11	27.27	28.4	29.32	25.03	26.0	26.91	32.77	34.13	35.23
90	24.19	25.2	26.0	30.68	31.96	32.98	28.16	29.33	30.27	36.86	38.4	39.63
100	26.88	28.0	28.9	34.1	35.52	36.65	31.3	32.6	33.64	40.96	42.67	44.03

Rough Methods.—(1) Grammes per square metre multiplied by 0.41 = weight 20 × 30 480's. Example: 30 × 0.41 = 12.30 lb. (2) Weight per ream 480's × 1464 ÷ area in inches gives grammes per square metre. Example: 15 × 1464 ÷ 25 × 20 = 44 grammes

STRAWBOARDS: EQUIVALENT NUMBER PER CWT.

Weight of Board.	22×32 704	20×25 500	20×30 600	24×38 912	25×30 750	27×34 918	28×36 1008	30×40 1200
4 oz.	448	631	526	346	421	344	313	263
6 „	299	421	354	231	281	229	209	175
8 „	224	315	263	173	210	172	156	131
10 „	179	252	210	138	168	137	125	105
12 „	149	210	175	115	140	113	104	87
14 „	128	180	150	99	120	98	89	75
16 „	112	158	131	86	105	86	78	66
18 „	100	141	117	77	94	77	70	59
20 „	90	127	106	69	84	69	63	53
1½ lb.	75	106	88	58	70	58	52	44
1¾ „	64	90	75	49	60	49	45	38
2 „	56	79	66	43	53	43	39	33
2¼ „	50	70	59	39	47	38	35	29
2½ „	45	63	53	35	42	35	31	26
2¾ „	41	58	48	32	38	31	29	24
3 „	37	52	43	29	35	28	26	22
3½ „	32	45	38	25	30	25	22	19
4 „	28	39	33	22	26	21	20	16

Basis, 22×32. The figures under size in heading indicate square inches

FRENCH AND BELGIAN SIZES OF PAPER

Name	*Size in Centimetres*	*Size in Inches*	*Name*	*Size in Centimetres*	*Size in Inches*
Grand Aigle	104 ×70	41 ×27⅝	Carré	56 ×45	22⅛×17¾
Grand Colombier	90 ×63	35½×24⅞	Coquille	56 ×44	22⅛×17⅜
Colombier	85 ×62	32½×24½	Petit Médian	53.3×40	21 ×15¾
Petit Aigle	84 ×60	33⅛×23⅝	Ecu	52 ×40	20½×15¾
Petit Colombier	80 ×60	31½×23⅝	Couronne	46 ×36	18⅛×14¼
Grand Soleil	80 ×57	31½×22½	Ruche	46.2×36	18¼×14¼
Elephant	77 ×62	30⅜×24½	Griffen	45 ×35	17¾×13⅞
Jesus	76 ×56	30 ×22⅛	Tellière	44 ×34	17⅜×13½
Jesus	70 ×55	27⅝×21¾	Propatria	43 ×34.5	17 ×13⅝
Super Royal	70 ×50	27⅝×19¾	Almasso	44 ×32.5	17⅜×12⅞
Petit Soleil	68 ×50	26⅞×19¾	Petit Raisin	43 ×32	17 ×12⅝
Raisin	65 ×50	25⅝×19¾	Pot	40 ×31	15¾×12¼
Royal	63 ×48	24⅞×19	Cloche	40 ×30	15¾×11⅞
Cavalier	62 ×46	24½×18⅛	Lys	39.7×31.7	15⅝×12½
Grand Médian	60.5×46	23⅞×18⅛	Rosette	34.7×27	13¾×10⅝

The above is a selection from an extensive range of prevailing sizes. The dimensions given are those most frequently used; but there is considerable variation in different qualities of papers and different makers

EQUIVALENT SIZES IN INCHES AND CENTIMETRES

Size		Inches	Centimetres	Size		Inches	Centimetres
Emperor	W	72 × 48	183.0 × 121.9	Demy	PC	22½ × 17½	57.1 × 44.4
Antiquarian	WD	53 × 31	134.6 × 78.7	Post	W	19 × 15¼	48.2 × 38.7
Double Elephant ..	WD	40 × 26¾	101.6 × 68.0	Pinched Post ..	W	18½ × 14¾	49.0 × 37.4
Atlas	WD	34 × 26	86.4 × 66.0	Foolscap	WD	16½ × 13¼	41.9 × 33.6
Colombier	WD	34½ × 23½	87.6 × 59.7	Pot	W	15 × 12½	38.1 × 31.7
Imperial	WDPC	30 × 22	76.2 × 55.9	Short and ⅓ Foolscap	W	22 × 13½	55.9 × 34.2
Elephant	WDC	28 × 23	71.1 × 58.4	Short and ½ Foolscap	W	24½ × 13½	62.2 × 34.2
Cartridge	C	26 × 21	66.0 × 53.3	Double Foolscap ..	W	26½ × 16½	67.2 × 41.9
Super Royal	WD	27 × 19	68.6 × 48.2	" " ..	PC	27 × 17	68.6 × 43.2
" "	P	27½ × 20½	69.8 × 52.1	Double Crown ..	PC	30 × 20	76.2 × 50.8
Royal	WD	24 × 19	61.0 × 48.2	Double Post ..	W	30½ × 19	77.5 × 48.2
"	PC	25 × 20	63.5 × 50.8	" "	P	31½ × 19½	80.0 × 49.5
Medium	WD	22 × 17½	55.9 × 44.4	Double Large Post ..	WP	33 × 21	83.8 × 53.3
"	WP	23 × 18	58.4 × 45.7	Double Demy ..	W	31 × 20	78.7 × 50.8
Large Post	W	21 × 16½	53.3 × 41.9	" "	P	35 × 22½	88.9 × 57.1
Copy	W	20 × 16	50.8 × 40.6	" "	C	35½ × 22½	90.2 × 57.1
Demy	WD	20 × 15½	50.8 × 39.3	Music Demy ..		20 × 15½	50.8 × 39.3

W, Signifies Writings; D, Drawings; P, Printings; C, Cartridges

COMPARATIVE WEIGHTS IN LBS. AND KILOS. CALCULATED ON BASIS OF 1016 KILOS. TO AN ENGLISH TON

Lbs.	Kilos.	Lbs.	Kilos.	Lbs.	Kilos.
1	0.454	23	10.433	84	38.100
2	0.908	24	10.886	90	40.822
3	1.361	25	11.340	100	45.358
4	1.815	26	11.793	112	50.800
5	2.268	27	12.247	120	54.429
6	2.722	28	12.700	130	58.964
7	3.175	29	13.154	140	63.500
8	3.629	30	13.608	150	68.036
9	4.083	31	14.061	160	72.572
10	4.536	32	14.515	170	77.108
11	4.990	33	14.967	180	81.643
12	5.443	34	15.422	190	86.179
13	5.897	35	15.875	200	90.715
14	6.350	40	18.143	224	101.600
15	6.804	45	20.411	250	113.393
16	7.258	50	22.679	300	136.072
17	7.711	56	25.400	336	152.400
18	8.165	60	27.215	350	158.750
19	8.618	65	29.483	400	181.429
20	9.072	70	31.750	500	226.786
21	9.525	75	34.018	560	254.000
22	9.979	80	36.286	1120	508.000

NOTE.—An easy way to find the nominal comparative weightis to multiply the number of pounds by 454, and divide by 1000. The result is number of kilos.

COMPARATIVE WEIGHTS IN KILOS. AND LBS. CALCULATED ON BASIS OF 1016 KILOS. TO AN ENGLISH TON

Kilos.	Lbs.	Kilos.	Lbs.	Kilos.	Lbs.
1	2.205	23	50.709	85	187.401
2	4.409	24	52.913	90	198.425
3	6.614	25	55.118	100	220.472
4	8.819	26	57.323	110	242.520
5	11.024	27	59.527	120	264.567
6	13.228	28	61.732	130	286.614
7	15.433	29	63.937	140	308.661
8	17.638	30	66.142	150	330.709
9	19.842	31	68.346	160	352.756
10	22.047	32	70.551	170	374.803
11	24.252	33	72.756	180	396.850
12	26.457	34	74.960	190	418.898
13	28.661	35	77.165	200	440.945
14	30.866	40	88.189	250	551.181
15	33.071	45	99.212	300	661.417
16	35.276	50	110.236	350	771.654
17	37.480	55	121.260	400	881.890
18	39.685	60	132.283	500	1102.362
19	41.890	65	143.307	600	1322.834
20	44.094	70	154.331	700	1543.307
21	46.299	75	165.354	800	1763.780
22	48.504	80	176.378	900	1984.252

NOTE.—An easy way to find the nominal comparative weight is to multiply the number of kilos by 1000, and divide by 454. The result is number of pounds.

To calculate the output of a machine:

Multiply the deckle width in inches by the speed in feet per minute; multiply the result by the substance of the paper in double crown (20×30) 480's. Divide the result by 400. The resulting figure is the number of pounds per hour.

Example: Deckle=130 inches. Speed=600 feet per minute. Substance= 20 lb. double crown 480 sheets.

$$\frac{130 \times 600 \times 20}{400} = 3900 \text{ lb. per hour.}$$

Another method:

To calculate the output of a machine: Multiply weight per ream by speed per hour in inches by width of web in inches, and divide the result by length of sheet multiplied by breadth of sheet and by number of sheets per ream.

$$\frac{\text{Weight per ream} \times \text{speed per hour in inches} \times \text{width of web}}{\text{Length of sheet} \times \text{breadth of sheet} \times \text{sheets per ream}}.$$

Example: Speed, 100 feet per minute. Deckle width, 68 inches. Substance, $16\frac{1}{2} \times 21 = 21$ lb. 500 sheets.

$$\frac{21 \times (100 \times 12 \times 60) \times 68}{16\frac{1}{2} \times 21 \times 500} = 593\ \tfrac{5}{11} \text{ lb. per hour.}$$

To find equivalent weights of different sizes of sheets: Multiply known ream weight by length and breadth of sheet, the weight of which is required, and divide the result by length and breadth of sheet the weight of which is known.

$$\frac{\text{Ream weight} \times (\text{length and breadth of sheet of unknown weight})}{\text{Length} \times \text{breadth of sheet of known weight}}$$

Example: Sheet $20 \times 25 = 25$ lb. per ream.

Find equivalent weight of sheet 20×30:

$$\frac{25 \times (20 \times 30)}{20 \times 25} = 30 \text{ lb.}$$

To find the weight of paper required for a web of a given length, breadth and substance:

Multiply the ream weight by the length of web in inches and by the breadth in inches; divide the result by the number of sheets per ream, multiplied by the length and breadth of sheet.

$$\frac{\text{Ream weight} \times \text{length of web in inches} \times \text{breadth of web in inches}}{\text{Sheets per ream} \times \text{length of sheet} \times \text{breadth of sheet}}$$

Example: Find the weight of paper required to produce a web 600 yards long by 30 inches broad, the paper being the substance of 20×30—25 lb. 500 sheets per ream.

$$\frac{25\times(600\times36)\times30}{20\times30\times50}=54 \text{ lb.}$$

To find the substance of paper in a web of given length, breadth and weight in any size of sheet and number of sheets per ream:

Multiply the weight of web by the length, breadth and number of sheets per ream, and divide result by length of web in inches and breadth of web in inches.

$$\frac{\text{Weight of web}\times\text{length of sheet}\times\text{breadth of sheet}\times\text{No. of sheets per ream}}{\text{Length of web in inches}\times\text{breadth of web in inches}}.$$

Example: Find the weight in 20×30—500 sheets of a web 600 yards long and 30 inches wide weighing 54 lb.

$$\frac{54\times500\times20\times30}{(600\times36)\times30}=25 \text{ lb.}$$

To find the weight of a web of paper:

Multiply width of web in inches by yardage, multiply result by substance in double crown (20×30) 480 sheets, divide result by 8000 and the result is the weight of the web in pounds.

Or

Multiply width of web in inches by yardage, multiply result by substance in demy 480's and divide by 5350. The result is the weight of the web in pounds.

To find the cubical contents of any square or rectangular vessel, multiply the length, breadth and depth together.

Example: Find the number of cubic feet in a tank 6 feet long, 4 feet wide and 3 feet deep:

$$6\times4\times3=72 \text{ cubic feet.}$$

To find the number of gallons a tank will hold, proceed as above and multiply the result in cubic feet by 6.2355, this being the number of gallons in 1 cubic foot.

Extending the above example:

$$6\times4\times3\times6.2355=448.956 \text{ gallons}$$

To find the weight of water in a tank, proceed as above and multiply the number of gallons by 10 (1 gallon of distilled water weighs 10 lb.).

Extending the above example:

$$6\times4\times3\times6.2355\times10=4489.56 \text{ lb.}$$

To find the cubical contents of a cylindrical vessel, square the diameter

(*i.e.*, multiply the diameter by itself), then multiply the result by 3.1416. Divide the result by 4, then multiply by depth.

Example: Find the cubical content of a vessel 4 feet in diameter by 3 feet in depth.

$$\frac{(4\times 4)\times 3.1416\times 3}{4}=37.6992 \text{ square feet.}$$

To find the number of gallons proceed as for a square or rectangular vessel (see previous examples).

To find the nominal comparative number of pounds in kilos: Multiply the number of pounds by 454 and divide by 1000. The result is the number of kilos.

Vice versa: Multiply the number of kilos by 1000 and divide by 454. The result is the number of pounds.

Bleach Liquor.—One cwt. (112 lb.) of dry bleaching powder of 36 per cent. strength produces approximately:

250 gallons of 5° Tw. liquor.
208 „ 6° „
178 „ 7° „

CYLINDRICAL TANKS: DIAMETERS, CIRCUMFERENCES, AREAS AND CAPACITIES

Diameter		*Circumference*	*Area*	*Capacity at 1-Foot Depth*	*Diameter*		*Circumference*	*Area*	*Capacity at 1-Foot Depth*
Ft.	In.	Ft.	Sq. Ft.	Gallons	Ft.	In.	Ft.	Sq. Ft.	Gallons
1	0	3.14	0.78	4.8	9	6	29.84	70.88	441.7
1	3	3.92	1.22	7.6	10	0	31.41	78.53	489.4
1	6	4.71	1.76	11.0	11	0	34.55	95.03	592.2
1	9	5.49	2.40	15.0	12	0	37.69	113.09	704.8
2	0	6.28	3.14	19.5	13	0	40.84	132.73	829.5
2	3	7.06	3.97	24.7	14	0	43.98	153.93	959.3
2	6	7.85	4.90	30.6	15	0	47.12	176.71	1101.3
2	9	8.63	5.93	37.0	16	0	50.26	201.06	1253.0
3	0	9.42	7.06	44.0	17	0	53.40	226.98	1414.5
3	3	10.21	8.29	51.7	18	0	56.54	254.46	1585.8
3	6	11.00	9.62	59.9	19	0	59.69	283.52	1766.9
3	9	11.78	11.04	68.8	20	0	62.83	314.15	1957.8
4	0	12.56	12.56	78.3	21	0	65.97	346.36	2158.5
4	3	13.35	14.18	88.4	22	0	69.11	380.13	2369.0
4	6	14.13	15.90	99.1	23	0	72.25	415.47	2589.2
4	9	14.92	17.72	110.4	24	0	75.39	452.38	2819.3
5	0	15.70	19.63	122.3	25	0	78.53	490.87	3059.1
5	3	16.49	21.64	134.9	26	0	81.68	530.92	3308.8
5	6	17.27	23.75	148.0	27	0	84.82	572.56	3568.1
5	9	18.06	25.96	161.8	28	0	87.96	615.75	3837.4
6	0	18.84	28.27	176.2	29	0	91.10	660.52	4113.7
6	6	20.42	33.18	206.8	30	0	94.24	706.86	4402.3
7	0	21.99	38.48	239.8	35	0	109.95	962.11	5992.0
7	6	23.56	44.17	275.3	40	0	125.66	1256.63	7826.3
8	0	25.13	50.26	313.2	45	0	141.37	1590.43	9905.2
8	6	26.70	56.74	353.6	50	0	157.08	1963.50	12228.6
9	0	28.27	63.61	396.4					

Useful Equivalents

Imperial

1 inch	= 25.4 mm.
1 foot	= 30.480 cm.
1 yard	= 0.9144 m.
1 furlong	= 0.2011 km.
1 mile	= 1.6093 km.
1 sq. in.	= 6.4516 sq. cm.
1 sq. ft.	= 0.0929 sq. m.
1 sq. yd.	= 0.8361 sq. m.
1 acre (4,840 sq. yd.)	= 4046.87 sq. m.
1 sq. mile	= 259.000 hectares
1 cu. in.	= 16.3872 cm.^{3}
1 cu. ft.	= 0.0283 m.^{3}
1 cu. yd.	= 0.7645 m.^{3}
1 pint	= 0.5682 litre
1 quart	= 1.1364 litres
1 gallon	= 4.5459 litres (277.419 cu. in.)
1 grain	= 0.0648 gramme
1 dram	= 1.772 grammes
1 oz.	= 28.349 grammes
1 lb (7000 grains)	= 0.4536 kg.
1 cwt.	= 50.80 kg.
1 ton	= 1.016 tonnes
1 h.p. (33,000 ft.-lbs. per min.)	= 745.9 joules per sec.
1 ft.-lb. (13,825.5 gm. cm.)	= 1.3562 joules
1 h.p. hr. (1,980,000 ft.-lbs.)	= 2,685,443 joules
1 watt-hr. (2654.31 ft.-lbs)	= 3600 joules per sec.

Metric

	In.	*Ft.*
1 millimetre	= 0.0393	= 0.0032
1 centimetre	= 0.3937	= 0.0328
1 decimetre	= 3.9370	= 0.3280
1 metre	= 39.3701	= 3.2808
1 kilometre	= 0.62137 ml.	= 3280.8

1 sq. millimetre	= 0.0015 sq. in.
1 sq. centimetre	= 0.1550 sq. in.
1 sq. metre	= 1.1959 sq. yd. (10.7639 sq. ft.)
1 are	= 119.59 sq. yds.
1 hectare	= 2.471 acres
1 cu. centimetre	= 0.0610 cu. in.
1 cubic metre (Stere)	= 35.3145 cu. ft. (1.3079 cu. yds.)
1 cu. centimetre	= 0.0338 fluid oz. (0.2705 fluid dram)
1 litre (1000 c.c.)	= 0.220 gal.
1 cu. metre (1000 litres)	= 220.083 gals.
1 milligramme	= 0.0154 grain
1 centigramme	= 0.1543 grain
1 gramme	= 15.4323 grains
1 kilogramme	= 2.2046 lb.
1 quintal	= 1.9684 cwt.
1 tonne	= 2204.62 lb. (0.9842 tons)
1 joule	= 0.7373 ft.-lb.
1 joule per sec. (1 watt)	= 0.00134 h.p.
1 metric h.p.	= 0.9863 h.p.
1 metric h.p. hr.	= 1,952,910 ft.-lb.

1 calorie or heat unit = amount of heat required to raise the temperature of 1 gramme of water 1 degree centigrade.

	Reciprocal.
1 lb. per sq. in. = 0.0703 kg. per sq. cm.	14.2234
1 lb. per sq. ft. = 4.882 kg. per sq. m.	0.2048
1 grain per gal. = 0.0142 gramme per litre	70.1160
1 lb. per 1000 gals. = 0.1 kg. per m.^{3}	10.0
1 Imp. gal. = 277.419 cu. in.	0.0036
1 Imp. gal. = 0.1605 cu. ft.	6.2278
1 Imp. gal. = 1.2003 U.S. gals.	0.8330
1 cu. ft. = 6.2278 Imp. gals.	0.1606
1 cu. ft. = 62.2786 lb.	0.0160
1 inch rainfall = 22,600 gals. per acre	
1 gal. per sq. ft. = 48.895 litres per sq. metre	0.0204
1 gal. per sq. ft. hr. = 1.17 cu. metres per sq. metre per day	0.8550
1 gal. per sq. ft. hr. = 1.92 vertical in. per hour	0.5200
1 gal. per sq. ft. hr. = 1,045,000 gals. per acre per day	
1,000,000 gals. per acre per day = 0.96 gal. per sq. ft. per hour	
1,000,000 gals. per acre per day = 1.84 vertical in. per hour.	

HEADS OF WATER AND CORRESPONDING PRESSURES

Head in Feet	*Pressure Lbs. per Sq. In.*	*Head in Feet*	*Pressure Lbs. per Sq. In.*	*Head in Feet*	*Pressure Lbs. per Sq. In.*	*Head in Feet*	*Pressure Lbs. per Sq. In.*
1	0.4335	2.3067	1	50	21.6753	80.7369	35
1½	0.6502	4.6135	2	75	32.5130	92.2707	40
2	0.8670	6.9203	3	100	43.3507	103.8046	45
2½	1.0837	9.2271	4	125	54.1884	115.3384	50
3	1.3005	11.5388	5	150	65.0260	138.4060	60
4	1.7340	13.8406	6	175	75.8637	161.4736	70
5	2.1675	16.1474	7	200	86.7014	184.5415	80
10	4.3351	18.4541	8	250	108.3767	207.6090	90
15	6.5026	23.0676	10	300	130.0520	230.6768	100
20	8.6701	34.6015	15	350	151.7273	288.3460	125
25	10.8377	46.1354	20	400	173.4028	346.0152	150
30	13.0052	57.6692	25	500	216.7534	403.6844	175
40	17.3403	69.2030	30	600	260.1041	461.3536	200

DEGREES OF HARDNESS OF WATER

	Clark	*German*	*Parts per 100,000*	*Metric (Parts per 1,000,000)*
Clark	1.0	1.25	0.7	0.07
German	0.8	1.0	0.56	0.056
Parts per 100,000	1.42	1.78	1.0	0.1
Metric (mg. per litre or parts per million)	14.2	17.8	10.0	1.0

pH VALUES

Pure distilled water, before exposure to atmosphere, at 22° C. = pH 7.0.
Pure distilled water after exposure to atmosphere = water + carbon dioxide = pH 5.7.

pH values over 7.0 denote alkalinity.
pH values under 7.0 denote acidity.

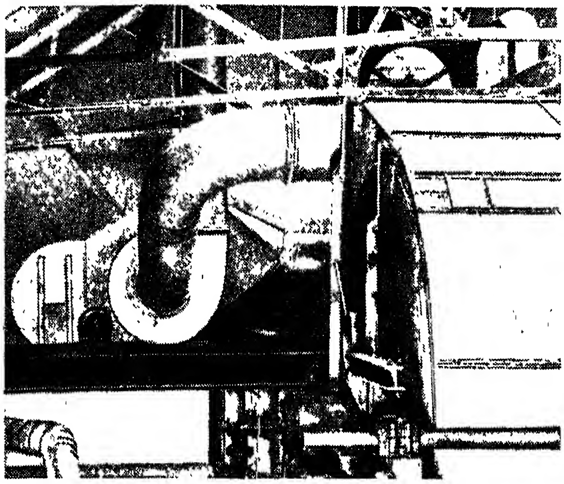
Hydrochloric acid	= pH	1.00
Acetic acid	= „	2.86
Pure water	= „	7.00
Sodium bicarbonate	= „	8.4
Ammonium hydrate	= „	11.3
Sodium carbonate	= „	11.6
Caustic soda	= „	13.1

SPECIFIC GRAVITY OF SOLUTIONS OF CAUSTIC SODA (60° F.=15° C.).

Twaddell	*Grammes per Litre* Na_2O	*Twaddell*	*Grammes per Litre* Na_2O	*Twaddell*	*Grammes per Litre* Na_2O
1	3.7	26	100.5	51	223.4
2	7.5	27	105.0	52	208.9
3	11.3	28	109.6	53	234.4
4	15.1	29	114.1	54	240.0
5	18.8	30	118.6	55	245.5
6	22.6	31	123.2	56	251.0
7	26.4	32	127.7	57	256.6
8	30.2	33	132.2	58	262.1
9	33.9	34	136.8	59	267.6
10	37.7	35	141.3	60	273.2
11	41.6	36	145.8	61	279.3
12	45.5	37	150.4	62	285.4
13	49.4	38	154.9	63	291.5
14	53.2	39	159.4	64	297.7
15	57.1	40	164.0	65	303.8
16	61.0	41	169.4	66	309.9
17	64.9	42	174.7	67	316.0
18	68.8	43	180.1	68	322.2
19	72.7	44	185.5	69	328.3
20	76.5	45	190.9	70	334.4
21	80.4	46	196.3	71	340.8
22	84.3	47	201.7	72	347.2
23	88.2	48	207.0	73	353.6
24	92.1	49	212.4	74	360.1
25	96.0	50	217.8	75	366.5

NOTE.—To find lb. soda (Na O) per cubic foot, divide grammes per litre by 16

INDEX



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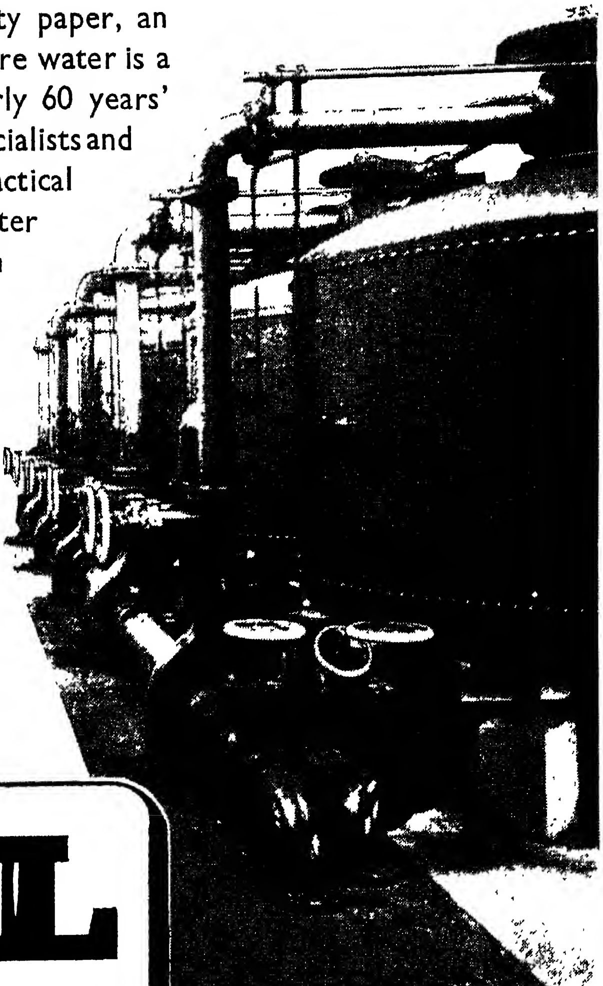

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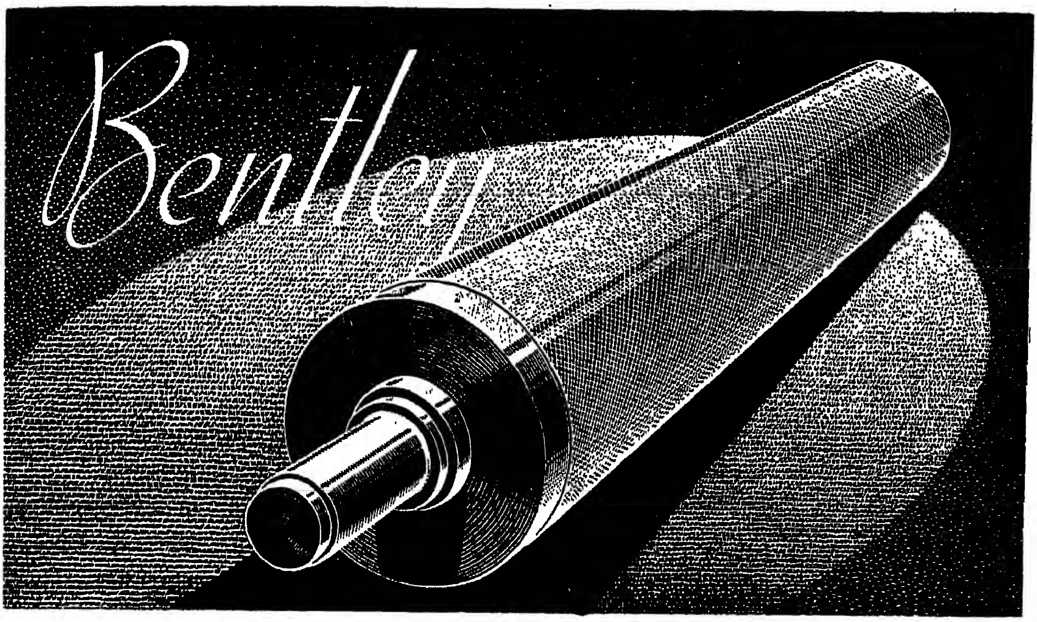

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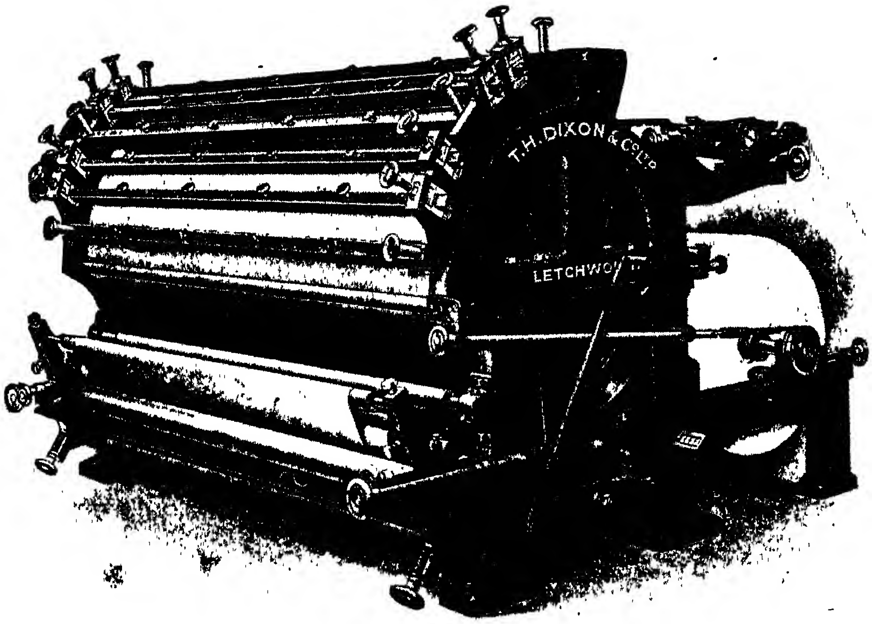

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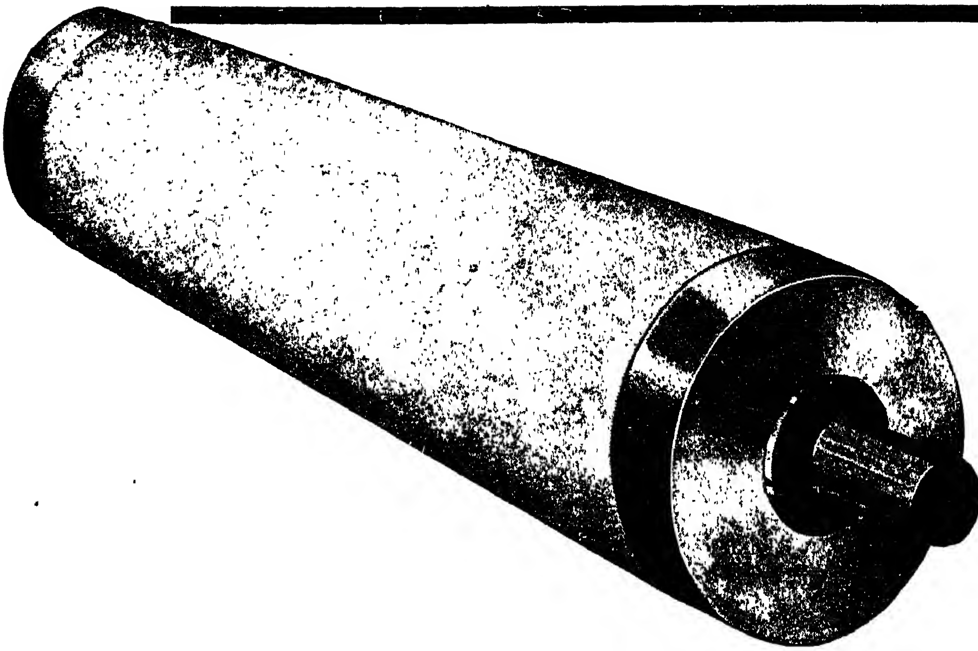

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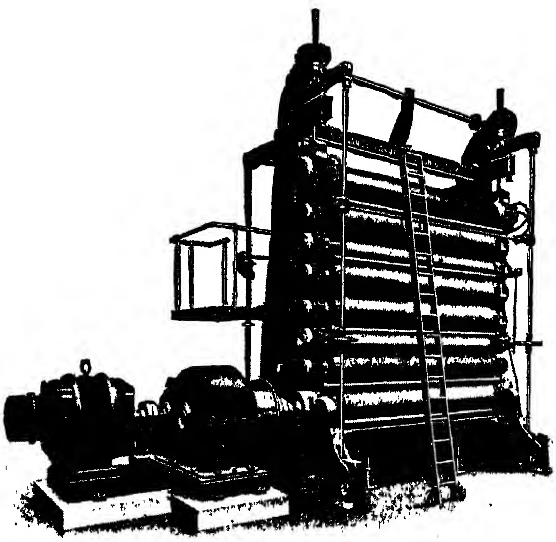

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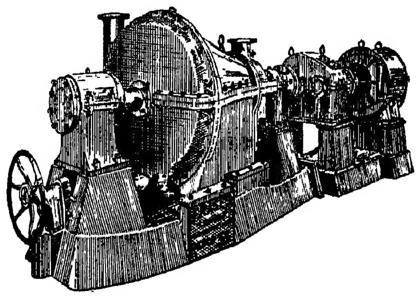

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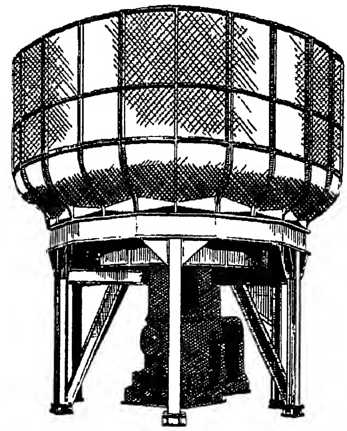

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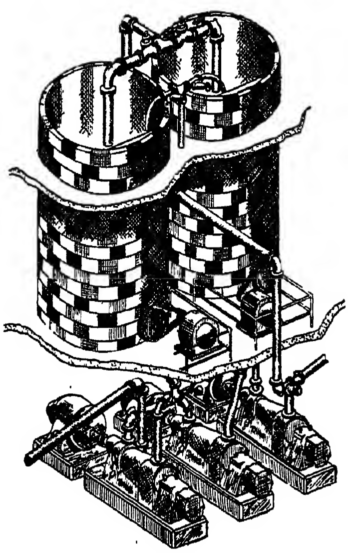

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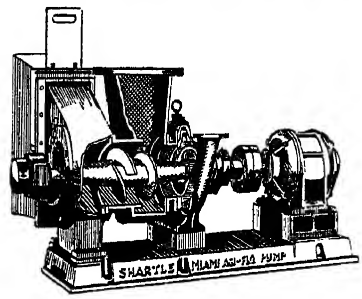

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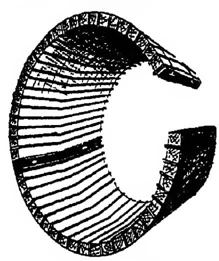

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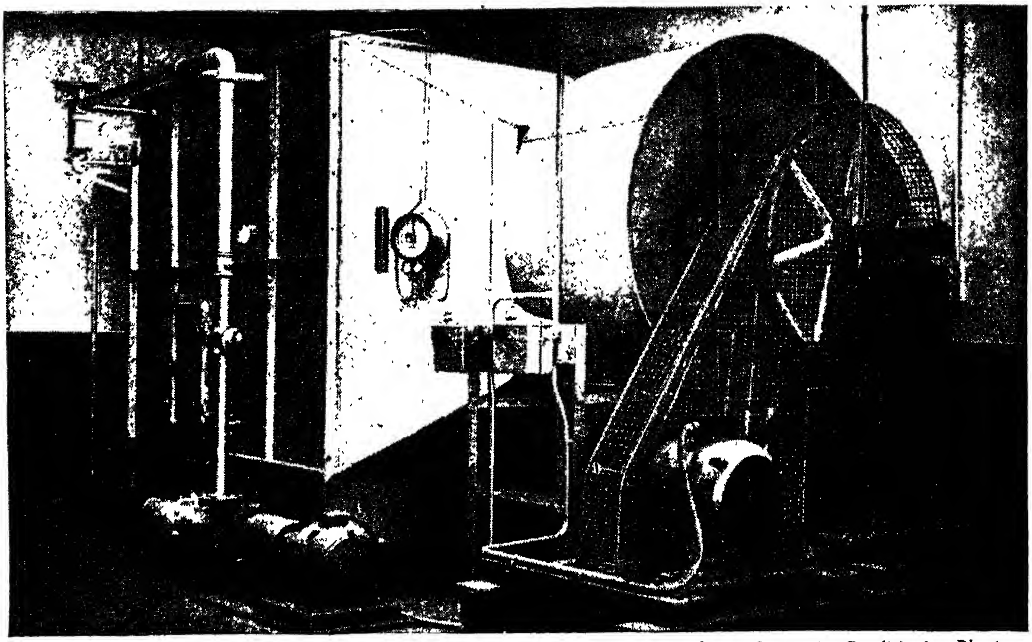

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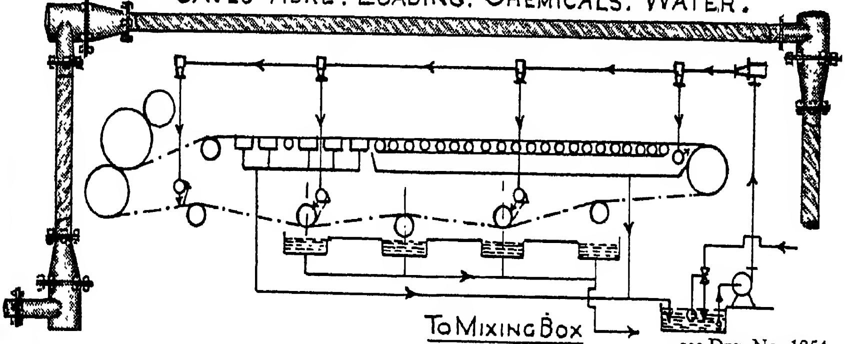

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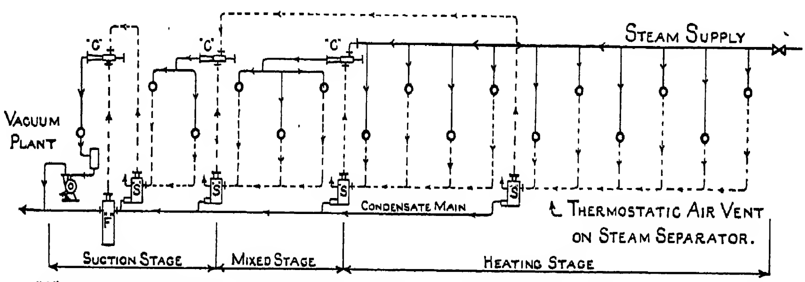

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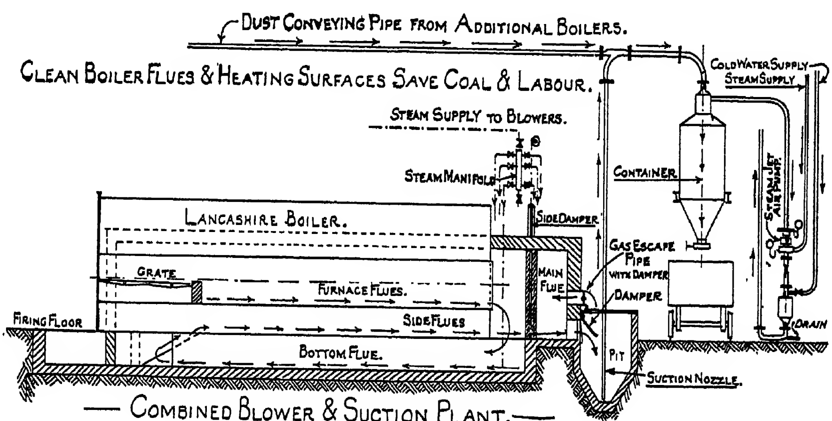

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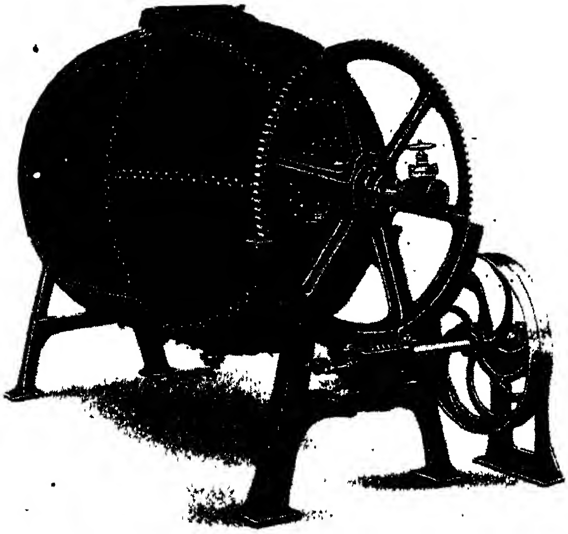

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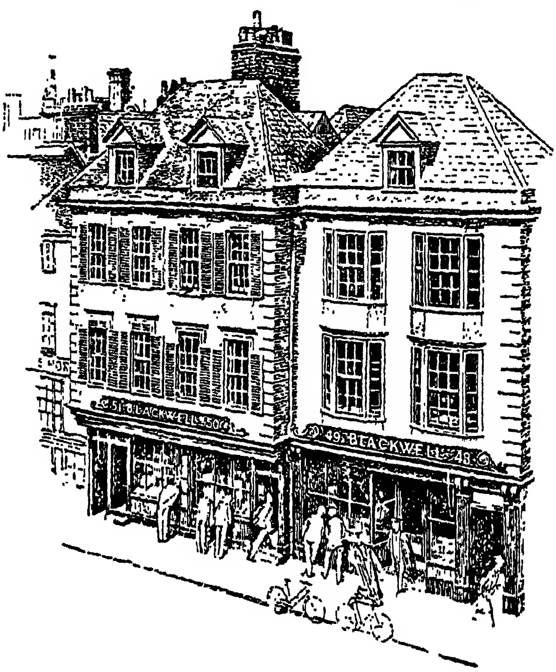

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